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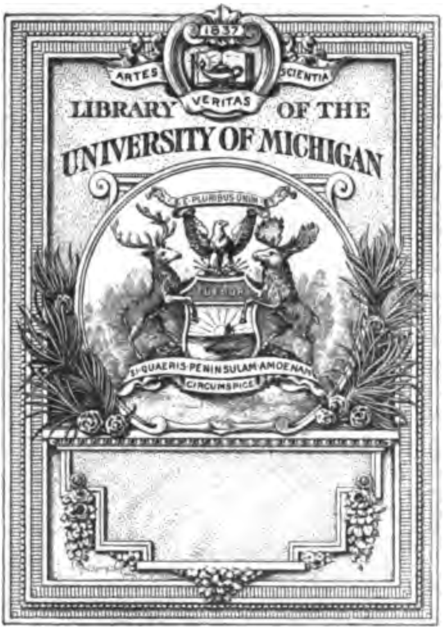
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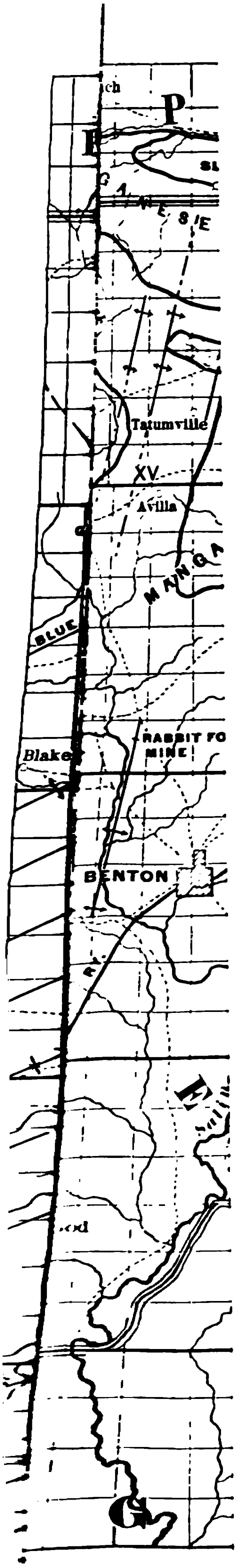
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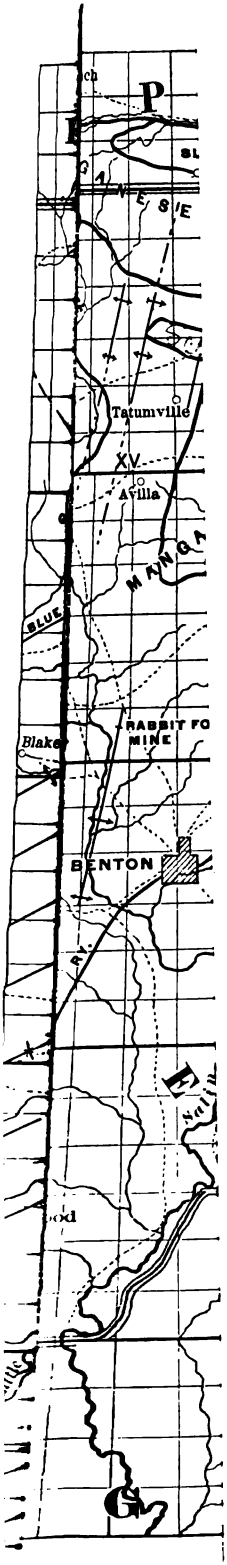
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ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY

OF

ARKANSAS,

FOR 1888,

IN FOUR VOLUMES:

VOL. I.	ADMINISTRATIVE REPORT. REPORT UPON THE GEOLOGY OF WESTERN CENTRAL ARKANSAS, WITH ESPECIAL REFERENCE TO GOLD AND SILVER.
VOL. II.	THE NEOZOIC GEOLOGY OF SOUTHWESTERN ARKANSAS.
VOL. III.	THE GEOLOGY OF THE COAL REGIONS.
VOL. IV.	MISCELLANEOUS REPORTS.

By JOHN C. BRANNER, Ph. D.,
State Geologist.

LITTLE ROCK:
PRESS PRINTING COMPANY.
1888.

OFFICE OF THE GEOLOGICAL SURVEY OF ARKANSAS,
LITTLE ROCK, NOV. 30, 1888.

To His Excellency,
Hon. Simon P. Hughes, Governor.

Sir:

Herewith I transmit my report upon the work done by the Geological Survey during the past year.

The benefits which the State must sooner or later derive from the Survey's work must be attributed, in a large measure, to the intelligent and cordial support which I have at all times received at your hands.

I have the honor to remain,
Your obedient servant,
JOHN C. BRANNER,
State Geologist.

ANNUAL REPORT, GEOLOGICAL SURVEY OF ARKANSAS.

1888.

VOL. I.

PART I. ADMINISTRATIVE REPORT FOR 1888.

By JOHN C. BRANNER, State Geologist.

PART II. REPORT UPON PRELIMINARY EXAMINATION OF THE GEOLOGY OF WESTERN CENTRAL ARKANSAS.

By THEO. B. COMSTOCK, Dr. Sc., Assistant Geologist.

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ADMINISTRATIVE REPORT.

JOHN C. BRANNER, STATE GEOLOGIST.

THE WORK OF THE MEMBERS OF THE SURVEY.

The following brief statement will show how the members of the Survey have been employed during the year. The publication of the full report of operations which is transmitted herewith renders it unnecessary, however, to make a more detailed statement in this place.

The State Geologist.—A large part of the State Geologist's time has been occupied by his administrative duties. He has given his time and his energies to directing and assisting his assistants; aiding them in every way in his power to do full justice to the work with which they have been charged, and to obtain the best possible results. The time he has been able to spend in the field has been devoted largely to the study of the geology of three small areas, the comprehension of which is necessary to a clear understanding of the general geology of the State. These areas are the region in the vicinity of Little Rock, the Magnet Cove, and a small area of igneous rock in Pike county. Much has also been done upon the general geology of the State and toward the preparation of the final report and the complete geologic map of the State.

The Assistant Geologists.—Dr. Theo. B. Comstock was appointed Assistant Geologist in June, 1887, and charged with the preliminary examination of the geology of those portions of the State said to yield the precious metals. He made a horseback journey through and a preliminary study of the following counties: Pulaski, Saline, Hot Spring, Garland, Montgomery, Polk, Scott and portions of Yell, Pike, Howard, Sevier and Franklin. He examined almost all the localities in the country traversed where gold or silver was being sought by mining, and collected material representing the character of the deposits. The results of Dr. Comstock's work are given in the present volume. The salaries allowed the assistant geologists being too small to admit of my retaining Prof. Comstock's services, he resigned October 31, 1887. During the summer of 1888 Dr. Comstock was employed for a few days that he might complete the work done in 1887.

The great importance of the geology of the coal regions of the State makes it necessary that especial attention be given to this branch of the Survey's work, at least, until the extent and general characters of the more important coal deposits be determined with sufficient care to serve as guides in the growth and development of the coal mining industries of the State. Mr. Arthur Winslow was therefore appointed Assistant Geologist and placed in charge of the Survey's work in the coal regions in November, 1887. Since that time he has made a reconnoissance of the coal region, and there have been constructed by him and under his supervision four detailed topographic and geologic maps covering an area aggregating 2080 square miles, upon which the limits of the coal beds have been as carefully laid down as the time and means at the Survey's disposal admit.

The varieties of coal occurring throughout the region have been sampled and these samples have been analysed in the Survey's laboratory. Mr. Winslow's work has been of the most valuable character possible, and the benefits which the State will receive from this branch of the Survey's work will pay for the entire cost of the Geological Survey many times over.

The salary paid the assistants is too low to long command the services of men so well qualified for their work as is Mr. Winslow. Unless provisions are made for a better salary the Survey will not be able to retain his services after the present year.

The Work of the Chemist.—Dr. R. N. Brackett, the Chemist, entered upon his duties August, 1887, and the laboratory was opened in September of that year. The following is a summary of the analyses and other work done by the Chemist and under his supervision. There have been made: 28 analyses of coals and one of lignite; 27 coking tests of coals; 65 qualitative analyses and determination of ores, and minerals; 27 quantitative analyses of soils, greensands, marls, limestones, chalks, mineral waters and river water; 46 sanitary analyses of well and other waters; 174 determinations of suspended matter and 160 of dissolved matter in Arkansas river water.

In the microscopic study of the crystalline rocks of the State 153 thin sections of rocks have been examined and reported upon, 103 of which sections were prepared in the Survey's laboratory.

The Work of the Topographic Assistant.—Mr. Chas. E. Taft, the assistant in charge of topographic work, has confined his attention principally to the field and office work upon the topographic map of the region about Little Rock. He has, however, spent some time in completing the Magnet Cove map, and, since the completion of his Little Rock map has made meridian determinations at the following points: Forrest City; Marianna; Helena; Clarendon; Lonoke; Fort Smith; Greenwood; Charleston and Clarksville. During the year past Mr. Taft has also taken charge of the Survey's series of field observations upon the Arkansas river, made for the purpose of determining its discharge and the amount of material carried down by it in suspension and solution.

Mr. Taft has devoted himself to his work with the greatest fidelity and it is to be regretted that the Survey is not able to command his services longer.

The Volunteer Assistants.—Some expression of appreciation is due the volunteer assistants, for the Survey, and indeed the entire state of Arkansas, is deeply indebted to them. With unselfish devotion, they have gratuitously given us the benefit of their time and services, of their technical knowledge and training, and have rendered us great and lasting benefits for which they have neither sought nor received other reward than the pleasures of scientific study and investigation. The results of the work of some of these gentlemen are embodied in the third and fourth volumes of this report, but in other cases the volunteer assistants have also taken the time and pains to prepare valuable papers for which they have received no adequate remuneration.

During the months of June and July the Survey received the volunteer services of Prof. R. Ellsworth Call, of Des Moines, Iowa, who received no compensation beyond his living and traveling expenses. In view of his special qualifications to deal with tertiary geology, Prof. Call was assigned to work in St. Francis county. In order that he might obtain as comprehensive view as possible of the tertiary geology of the adjoining country he was sent to Camden, Arkadelphia and to points of interest in Jefferson and Phillips counties. Other duties obliged him to stop his work earlier than he had anticipated. Since that time he has prepared, at great inconvenience to himself, and at no expense to the Survey, a finely illustrated report upon St. Francis county, which will be of great value in the further study of the tertiary geology of the State as well as in its description of the geologic structure of that particular county. Prof. Call's report is accompanied by a map of that part of St. Francis county which lies west of the St. Francis river, and includes also a small portion of Cross county. This map was constructed from actual surveys made by the Geological Survey. It contains also a number of instructive sections and figures for the elucidation of the geology of the region, all of which have been drawn by Professor Call himself.

Dr. O. P. Hay, of Butler University, Irvington, Indiana, during the summer of 1887 traced the northern limits of the mesozoic rocks of southwestern Arkansas from Arkadelphia to Ultima Thule. The results of this work form part of the second volume of this annual report. Dr. Hay received no remuneration beyond his expenses, but was paid for preparing his report. Mr. Chas. H. Bollman who accompanied Dr. Hay, rended valuable assistance, and the results of his work are embodied with those of Dr. Hay. This work has been of great utility to Professor Hill, who subsequently studied and reported upon the mesozoic geology of southwestern Arkansas.

Mr. F. V. Coville was one of the volunteers during the summer of 1887. His work was done chiefly in Independence county, and his observations upon geology will be embodied in the final report of the State Geologist. Being a professional botanist,* Mr. Coville was asked to prepare a list of the plants of the State. He studied the flora about Little Rock and in White, Jackson and Independence counties with this object in view, and has lately completed his lists of the plants of Arkansas which is now in my hands awaiting publication. Mr. Coville has prepared this list at no small inconvenience to himself, and has received only his expenses from the time he left until he returned to his home in New York.

Dr. Chas. H. Gilbert, Professor of Biology at the University of Indiana, volunteered his services during the summer of 1888. He accompanied and assisted Mr. Winslow in the construction of a geologic section across the southwestern portion of the State, and did valuable work upon the igneous rocks of Pulaski county. Dr. Gilbert's services were unfortunately interrupted by illness. The result of his work will be embodied in the fourth volume of this report.

Professor Seth E. Meek of Cedar Rapids, Iowa, volunteered his services during the summer of 1888, and was assigned to work in Johnson county, where he assisted Mr. Winslow in the study of the geology of the coal fields. The results of Professor Meek's work will be embodied in the report upon the coal regions.

Mr. C. H. Gordon of Keokuk, Iowa, volunteered his services during the summer of 1888, and aided Mr. Winslow in Sebastian county. His work was unfortunately interrupted by illness in his family, and he was obliged to return home before the close of the season. His results will form a part of the third volume of this year's reports.

---

*Mr. Coville was formerly instructor in botany in Cornell University, and is now Assistant U. S. Botanist in the Department of Agriculture at Washington, D. C.

The State Geologist has been offered the services of several other geologists of whose knowledge and skill he would have gladly availed himself, but for the smallness of the fund from which their necessary expenses would have to be paid.

Co-operation of the United States Geological Survey.—The State Geologist has been fortunate in securing the co-operation of the Director of the United States Geological Survey, at Washington. As the result of a personal conference with the Director in New York during the summer of 1887, Professor R. T. Hill, one of the members of the National Survey was assigned to work in Arkansas under the direction of the State Geologist. Professor Hill reported at Little Rock, in September, 1887, and was assigned to work in Clark county. Later his field was so extended as to embrace the entire mesozoic region of the State, including those parts of Clark, Pike, Hempstead, Howard, Sevier, Little River and Nevada counties lying north of the Iron Mountain railway and south of the paleozoic border. From the time Professor Hill began work here in September, 1887 to December, 1888, when his completed report was placed in my hands, the United States Geological Survey has given us the full benefit of his services at no other cost than that of his field expenses. The results of this work are given in the second volume of this annual report. It will be of great and lasting benefit to the State of Arkansas, though it has been accomplished at only the nominal cost of the field expenses of the assistant doing the work Some of the valuable results of the co-operation of the United States Geological Survey are mentioned under the head of volume II, on page XXIV.

Assistance of the United States Coast and Geodetic Survey.—Application was made by the Governor, in 1887, to the Superintendent of the United States Coast and Geodetic Survey for the establishment in elevation of points in the State for the use of the Geological Survey. The funds of the Coast Survey available for such work having already been allotted, this assistance could not be rendered. Later the State Geologist conferred personally with the Superintendent of that bureau, and a line of precise levels was run by the United States Coast and Geodetic Survey, connecting the city of Little Rock with tide elevations on the Gulf of Mexico. Upon the request of the State Geologist, another party was sent by the United States Coast Survey to carry these precise levels westward along the Little Rock and Fort Smith railway. This line was carried as far as London, in Johnson county. Permanent bench marks have been established at every railway station and town along the entire length of this line of levels from Arkansas City to London. The elevations determined will be of great service in the construction of accurate maps by our Geological Survey. Important as this work is, in view of its expensiveness, the State Geologist has not felt warranted in undertaking it. The aid of this national bureau, however, has entirely relieved the State of the expense of the work, which has amounted to not less than $3000

Local and Temporary Assistants.—During the year several local assistants have been employed.

Professor Simonds of the Arkansas Industrial University, at Fayetteville, was engaged for two months, July and August, 1887, as a special local assistant, to work up the geology of Washington county. Since then, however, he has given to this study all the time he could spare from his University duties. The Survey paid his field expenses up to August, 1888, but since that time he has not only given his services freely but has borne his own expenses and furnished his own instruments. Dr. Simond's report, maps and sections have been prepared with the utmost care, and speak for themselves.

Mr. Gilbert D. Harris has been employed during the present year up to November 30. He worked out in detail the geology of two and one sixth townships in Washington county, and mapped the topography and geology of thirteen townships in Pope and Yell counties. His map, cross-sections, columnar sections and descriptions are among the most accurate parts of the Survey's work during the past year, and reflect great credit upon their author. He also did some work upon the Ozark-Clarksville sheet of the geologic maps of the coal region. As Mr. Harris has been employed only as a local and temporary assistant, it is cause for great regret that the Survey has not been able to pay him anything like an adequate salary for his services. Several months of his time have been devoted to this work gratuitously, he having received only his living and traveling expenses, and he has been obliged, in addition, to personally meet the expenses and undergo the inconveniences of a long and serious illness, brought on by his zeal in his work and his disregard for personal comfort while in the field. It is to be regretted that the Survey cannot retain Mr. Harris's valuable services.

Mr. W. J. Hutcherson was employed for the most part in topographic work. He aided in the construction of the topographic map of the igneous outburst in Pike county, made a section seventeen miles long from the mouth of Prairie creek northward; he did the instrumental work in the preparation of the geologic section from Arkadelphia to Hot Springs; he did most of the topographic work upon the map of the Magnet Cove region; assisted in the topographic work upon the Little Rock map, and ran a number of level lines in connection with the last mentioned work. Mr. Hutcherson devoted himself to his work with a fidelity and an enthusiasm of which it is difficult to speak in terms of moderation. Whatever was entrusted to him he did with zeal, judgment and dispatch. While at work upon the Little Rock map Mr. Hutcherson fell ill, and died in this city on the 12th of June after a very brief illness.

Mr. J. Perrin Smith has been with the Survey since January 1, 1887, for five months employed as a local assistant, and during the remainder of the time as a volunteer assistant. Most of his time has been spent in the chemical laboratory where he has shown himself a trustworthy and earnest assistant.

Prof. J. H. Shinn was engaged to collect and edit a report upon the mineral statistics of the State for 1887. He has, however, very generously given much more time to the preparation of the report than the Survey was able to pay for.

Messrs. A. G. Taff, J. A. Taff, H. E. Williams, W. N. Crozier and N. F. Drake, all of them students in the Arkansas

University, have been employed at various times in topographic and office work. These young men have, without exception, shown themselves to be capable, faithful and zealous workers.

Mr. Louis L. Smith of Hot Springs was employed from Sept. 13, 1887 till Oct. 31, 1888 as a rodman, and he has performed his duties with the greatest fidelity.

SUBJECTS TREATED IN THE ANNUAL REPORT.

Last year the Survey had been in existence for so short a time when it became necessary, according to the law creating the Survey, to issue an annual report, that nothing more than an administrative statement could be published. The present annual report, however, contains the results of most of the work done since the beginning of operations in June, 1887. It is contained in four volumes. This division of the annual report is made because the smaller volumes are both cheaper and more convenient. The demand for any one volume, or part of the report will not be so great as the demand for the total number of separate parts. So large an edition, therefore need not be issued as would become necessary in case all the volumes were bound in one.

Volume I.—This volume contains a brief administrative report giving a general account of the work upon which members of the Survey have been engaged during the year. The bulk of the volume, however, consists of the report of Dr. T. B. Comstock, Assistant Geologist, upon his preliminary examination of the mineral resources of the western central portion of Arkansas with especial reference to the production of the precious metals. It gives the results of his work in detail, and is accompanied by tables of analyses and assays of the material collected by him, and by two small maps of the region traversed.

Volume II.—The second volume, by Professor Robert T. Hill, gives the results of the combined work of the U. S. Geological Survey, and of the Geological Survey of Arkansas, upon the mesozoic geology of the State.

This volume is accompanied by a map showing the geology of the mesozoic area of the State, and the distribution through it of the various formations It contains also three profile sections which illustrate the arrangement of the various strata, and four plates showing some of the fossil remains characteristic of the various formations. These plates of fossils have been furnished by Professor Hill, the assistant who did the work and prepared the report, at no expense to the Survey.

The great value of the timely co operation of the United States Geoloical Survey will be apparent from the following brief summary of the more important economic results brought out in this volume, as follows:

1. The discovery of vast deposits of true chalk in southwestern Arkansas.

2. The discovery in the State of inexhaustible supplies of greensand marls.

3. Calling attention to the extent and value for agricultural and other purposes of our gypsum deposits.

4. The discussion of the uses and value of our mineral fertilizers and of their adaptability to our own soils.

The fourth volume contains also the report by Dr. O. P. Hay upon the work and observations made by him while tracing the northern border of the cretaceous deposits of the State.

Volume III.—The third volume by Mr. Arthur Winslow, Assistant Geologist, relates entirely to the geology of such parts of the coal regions as the Survey has been able to work out in detail during the past year. It is accompanied by four maps and a large number of profile and columnar sections which display the geologic structure and the relations of the various formations to each other in the plainest manner possible.

Of the maps accompanying the third volume, Sheet No. I covers an area of about 570 square miles in northern Scott, western Logan, southern Sebastian and southwest Franklin counties.

Sheet No. II covers 510 square miles in northern Sebastian, southern Crawford and western Franklin counties.

Sheet No. III covers 530 square miles in northern Logan, southern and eastern Franklin and southern Johnson counties.

Sheet No. IV covers 470 miles in southern Pope county and northern Yell county.

All these maps are constructed upon a scale of one mile to the inch and are, therefore, of convenient size, and yet not so small but that the salient topographic and geologic features can be delineated upon them. In addition to the features ordinarily represented upon maps, such as the roads, streams, towns, townships, sections, etc., the forms and positions of hills, valleys, ridges and mountains are delineated with great care by means of contour lines drawn 20 feet apart vertically. The elevations are all referred to the sea level on the Gulf of Mexco, so that both relative elevations and the elevation above the Gulf at any point upon the map may at once be determined by reference to the contour lines.

The positions are also given of all coal openings and prospect holes, and wherever it has been possible to obtain them for publication, the records of borings are given in the report.

One of the most important pieces of information conveyed by these maps is the outlining of the areas over which coal occurs, and the distinguishing of these areas upon the map by means of a tint. At the same time the axes of all the important folds have been located. By reference to these sheets then anyone can ascertain at once the limits of our coal beds over the region represented, and by reference to the axes, the mining companies will be enabled to direct their operations economically.

The cross sections accompanying these sheets have been made to cross the axes of the folds from north to south, and upon them are shown the various formations and their relations to each other as far as they are now known.

The publication of these maps will convey so clear an understanding of the geology of the coal regions that every person interested in coal or in coal lands will know where to seek and where not to seek coal.

In connection with the field work done in the coal regions, a number of carefully selected samples of coal has been collected and analyses of them have been made in the Survey's laboratory. Coking tests have also been made of many of these coals, and where they have held out promise of being valuable for coking purposes they have been sent to the St. Louis Sampling and Testing Works where they have been treated upon a large scale. Tests have also been made of several of our more important coals to determine their fuel values for various purposes as compared with Pittsburg coal. The results of these tests are given in full in the third volume.

Volume IV.—The fourth volume contains the following miscellaneous reports:

1. Report upon the geology of Little Rock. This is accompanied by a detailed topographic map of an area of 99 square miles of the region about the city, and published on a scale of 1800 feet to the inch.

2. Report upon the geology of the Magnet Cove region. This is accompanied by a detailed topographic and geologic map covering an area of twelve square miles.

3. A report upon the igneous rocks of Pike county, accompanied by one page plate.

4. The geology of St. Francis county, accompanied by a topographic and geologic map and by a number of geologic sections.

5. The geology of the Fayetteville region of Washington county, accompanied by a geologic map on a scale of one mile to the inch, covering an area of 252 square miles and by numerous sections illustrating the geology of the region discussed.

6. A geologic section from Arkadelphia north to the Arkansas river.

7. A series of observations upon the geologic work done by the Arkansas river extending over one year.

8. The precise leveling done for the Survey by the U. S. Coast and Geodetic Survey during the year.

9. Report on the work done in the Chemical Laboratory during the year. The results of the chemical work are given under the following heads:

a. Ores and Minerals;

b. Soils, Marls, Limestones, Chalks, Clays;

c. Coals and Cokes;

d. Mineral Waters;

e. Sanitary Water Analyses;

f. Arkansas River Water and its Sediments;

g. Miscellaneous Analyses.

10. The Crystalline Rocks of Arkansas.

11. Mineral Statistics for 1887 and 1888.

12. The Climate of Arkansas.

Besides the subjects reported upon in these four volumes a vast amount of valuable information has been gathered by the Survey relating to the geology and natural history of the State, but inasmuch as this information is more or less fragmentary, it cannot be advantageously published at present.

INTRODUCTION TO THE REPORT UPON WESTERN CENTRAL ARKANSAS.

In the summer of 1887 Dr. T. B. Comstock, Assistant Geologist, was charged with the preliminary study of the geology of those parts of western central Arkansas in which gold and silver were said to exist. He left Little Rock in June of that year, and made a horseback trip through the counties of Pulaski, Saline, Garland, Hot Spring, Montgomery, Polk, Scott, and portions of Yell, Pike, Sevier, Howard, Logan, Franklin and Scott, planning his route so as not to retrace his course. He visited all the important places in the State where mining or prospecting for gold and silver was being or had been carried on, collected in place material illustrative of the various formations, and, by personal inspection, obtained data necessary to the formation and expression of a trustworthy opinion regarding the status of the workings. In the summer of 1888 he was again employed for a short time for the purpose of supplementing his observations of the preceding year.

In connection with the immediate objects of Dr. Comstock's investigation, he was directed to make such observations as he conveniently could, without losing sight of the principal object of his work, upon the occurrence of the baser metals throughout the district traversed by him. These observations have rendered possible the chapters upon manganese, zinc, lead, copper, etc., in the second part of the report. It should be understood, however, that the Survey has not, as yet, been able to study the occurrence of these metals in those portions of the State outside of the district traversed by Dr. Comstock, and that, for this reason, no reference can be made to them in this place. It should also be remembered that whatever is given in addition to the report upon gold and silver is incidental to the main objects of the investigation, and

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that it therefore makes no claim to completeness, even in the region of which the report treats.

A general review of the geology of the district has been prepared for this report, but the determinations of the geologic ages of the various formations are involved in so much doubt that it does not seem best to commit the Geological Survey to conclusions based upon anything short of a complete study of the region in question

In Part I the general geology of the region traversed and the evidence collected in the field are presented, though much of economic importance is given also in this connection. In Part II the economic geology, with especial reference to the occurrence of gold and silver, and the facts brought out by the examination of the evidence in the office and laboratory, are treated.

Pains have been taken to make the report as plain as the nature of the subjects admits. It is impossible, however, to entirely dispense with all technicalities in discussing scientific subjects.

A word is necessary regarding the two maps accompanying this volume. The system of east-west folds in the rocks of the State south of the Boston Mountains and north of the mesozoic border in the southwest is one of the most marked features in the geology of Arkansas. In some portions of the State, notably in White and Faulkner counties, the axes of of these folds are very nearly east-west lines; at Little Rock the strike of the rocks is a little north of west and south of east, while further west the strike is, for the most part, about five degrees south of west and north of east. There are, of course, many local variations in the direction of these folds, some of them changing their bearing as much as thirty degrees in a distance of five miles. The geology of the whole region between Little Rock and the Indian Territory line has not been sufficiently studied to determine whether or not any of those axes are persistent across the entire distance. As far as the observations of the Geological Survey go, however, they favor the theory of interrupted overlapping folds, and I am, therefore, inclined to accept the long and regular axes shown upon the accompanying map only in a modified sense.

It should be remembered, on the other hand, that the geology of the section treated of is the most complicated, and of more interest to the geologist than that of any similar area of the State. Its detailed study must be of the greatest service in the comprehension of the geology of the State as a whole. This detailed study, however, it was quite impossible for the assistant charged with the work to undertake.

The illustrative material collected by Dr. Comstock has been examined with the greatest care by himself, by the Chemist of the Survey, and by other assayers and chemists, and the results of these examinations agree so exactly that there is no valid reason for doubting the conclusions based upon them and announced in the present report.

That the results of the Survey's investigations of the gold mines of the State must prove a disappointment to many, and that they will excite the animosity of others, are foregone conclusions. Public welfare and official integrity, however, alike demand that these results be made known.

A full index at the end of the volume will be of service to those seeking specific information.

JOHN C. BRANNER.

A PRELIMINARY EXAMINATION

OF THE

GEOLOGY OF WESTERN CENTRAL ARKANSAS.

THEO. B. COMSTOCK ASSISTANT GEOLOGIST.

LETTER OF TRANSMITTAL.

UNIVERSITY OF ILLINOIS,
CHAMPAIGN, ILL., NOV. 20, 1888.

SIR:—I have the honor to forward herewith my report upon the work assigned to me, viz: the preliminary investigation of the metallic resources of Arkansas, with particular reference to the ores of the precious metals.

As limited by the necessities of the case, the territory examined covered the greater part of a tract embracing the counties of Pulaski, Saline, Garland, Hot Spring, Montgomery, Polk and Scott, as well as smaller portions of Pike, Howard, Sevier, Logan and Franklin counties. It is probable that no gold or silver ores of commercial value occur in other counties, but it is well known that important deposits of the base metal ores exist outside of the district assigned me. The absence of any report upon the latter is due to the fact that they have not been examined by the Survey, for it was impossible to extend this work, during the time at my disposal, beyond the area in which the precious metals were being sought by mining.

The field work upon which the accompanying report is based might have occupied more time, had the mining districts been sufficiently developed to warrant more detailed studies; but the provision made for the Geological Survey was such that I deemed it to the interest of all concerned to leave the more minute investigations, which a productive industry may hereafter justify, until the time when more abundant support may be given the Survey. My resignation from the Survey was put into your hands in the autumn of 1887. Since the date of its acceptance, I have, however, devoted all the time at my disposal to the preparation of this report.

My thanks are due to so many of the citizens of the counties traversed that a long list would be required to even name them. Among them all there is not one from whom anything but the most courteous treatment was received. I cannot refrain from mentioning particularly Col. E. W. Rector, of Hot Springs, whose kind attentions made possible much more than could otherwise have been done in the same time.

To yourself, in your official capacity, far more credit should be given than will appear in the pages of this volume. But for your constant aid and encouragement and for your very numerous friendly acts, the work in the field and in the office would never have been accomplished. With sincere esteem,

Very respectfully,

THEO. B. COMSTOCK,
Assistant Geologist.

To Dr. John C. Branner, State Geologist of Arkansas.

PART I.

STRUCTURAL GEOLOGY.

CHAPTER I.

Pulaski County.

The country north of Little Rock is occupied by rocks which will require special study for a complete understanding. The arrangements made by Dr. Branner contemplate a much more detailed examination than has been possible for the purposes of this report, but a brief review may be here given. This region requires detailed study with good topographic maps in hand. The important folds which can be readily traced west of the Batesville road die out in part north of the Arkansas river, and the dislocations which have been produced by the igneous ejections of the Fourche Mountains, are somewhat complicated when examined without reference to other regions. By traversing the country north of the river, and especially along the line of the Little Rock and Fort Smith railway from Palarm to Little Rock, a much more satisfactory section is obtained, as the remnants of the folds are mostly exposed in the railway cut. In this way observations were made which go far to explain the geologic irregularities of the region. Two or three folds of low degree were made out in going northward over the Batesville road, but only one of these was clearly defined. In following the river valley from Marche southward, the railway excavations give a very fair exposition of the structure. Near A. F. Rice's on the northeast quarter of the northwest quarter of section 23, 3 N., 13 W., the tough, bluish, quartzitic rocks dip S. 27° E., 65°. On the line between sections 23 an

14, there is an exposure of tough, dark, quartzitic rock, finely jointed, with a network of thin quartz seams, apparently in the axis of an anticline.*

As far as can be made out the southeastward dip continues along the Little Rock and Fort Smith railway, as far as a little ridge a quarter of a mile west of the 7-mile post, where a shallow syncline is well shown in a railroad cut through the ridge. Coming southward the northward dip is then evident to near the 5-mile post where the rocks become vertical and again return to the southward dip. The anticline here is not topographically important. The low south dip continues to a point about three miles from the city. In a little cut where the railway passes near and in front of a house at the crossing of the railroad by the wagon-road, a very shallow syncline appears, passing directly under the house itself. From this point to Little Rock the rocks dip to the north, the pitch gradually increasing.

In section 13, 3 N., 12 W., the Batesville road passes over a high tract followed by a sudden transition to flat land, with a second ridge beyond. The ridges which thus stand out boldly in the relief may be traced for miles to the westward, bearing a few degrees south (strike about S. 63° W.), and the northeastward continuation of the same features are well marked. There is reason for considering this a fault line, which apparently follows closely the axis of an uplift. Tracing this course towards the Arkansas river, and studying the topography of the intervening country, there is little doubt that the anticline observed near the 5-mile post on the Fort Smith railway is a part of the same disturbance.

The Welldiggen Mining Claim.—In the northeast quarter of section 19, 3 N., 11 W., there is some evidence of former mining work upon the land of Dr. Watkins. At present there is very little upon which an opinion can be based, for the old shaft is filled with debris and water, and but little of the reported product is visible upon the dump. The shaft was sunk to the depth of eighty feet. A few pieces of galena and zinc blende were picked out of the soil about the excavation by the writer, which indicate a fair quality of ore, yielding some silver, besides the lead and zinc due from these minerals. But there is very little in the outcrops to explain the mode of occurrence of this material, as the geologic structure is obscured by heavy alluvial deposits.

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*This is identical with the so-called Golden Wonder quartz of Bear City, Montgomery county. It carries no gold, but it is reported that galena was found in digging the cellar of a house which is but a few rods south of the axis on the northeast quarter of section 24.

The Kellogg Mines.—Southward from the old Welldiggen shaft, two other prominent workings have exposed ore-bodies of some importance. These and a number of pits sunk here and there over the adjoining area have served in a measure to define the course of the deposit, which seems to follow closely the direction of the anticlinal axis marked out in a preceding paragraph.* The greatest amount of development has been made at the Confederate shaft in the southeast quarter of section 19, where there are large dumps and the relics of heavy machinery of rude pattern, mostly of timber. At this point there is now (July, 1888,) no opportunity to study the structure, owing to the neglected condition of the mine and the waste produced by time. The history of explorations in this place, according to apparently authentic traditions, dates back more than forty years.

The Survey's assays of material collected by the writer, practically confirm the favorable results reported from this district, although it is probable that the general average of the product has not been of the highest grades, and it requires somewhat close but not difficult assorting to maintain the best results. Notwithstanding the rather large amount of work which has been done at the Confederate shaft, the managers do not appear to have acquired a very clear conception of the nature of the property. Besides this, the equipment did not comprise adequate pumping facilities for the drainage of an extensive mine. Accordingly, no very deep working could be undertaken, and the successive attempts at exploitation have been fitful and of a temporary character. Instead of adopting a well matured plan of comprehensive development or exploration, the deposit has been sought through numerous trial pits to avoid the difficulties of drainage and ventilation which might ensue from the connection of underground workings.

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*As an instrumental survey has not been made it cannot be positively stated that the Welldiggen and Kellogg workings are upon the same belt, but the geological indications and the estimated positions of the excavations make this highly probable.

The latest developments (July 19, 1888,) have been carried on at a spot about three hundred yards north of east of the old Confederate shaft, following the strike of the deposit, which is apparently conformable to the stratification of the country rocks. Here a steep slope (58°) bearing nearly south (magnetic), has been sunk through black shales which dip 38°–42° S., 27° E., thus cutting the beds obliquely both in dip and strike. This slope, known as the German shaft, crosses a seam of zinc blende 35 feet below the surface. At this point a drift has been run westward upon the mineral deposit in the direction of the Confederate shaft. The ore is a well defined streak of very pure crystalline sphalerite from three to six inches thick, thinning and swelling and occasionally rolling over to a lower inclination, but practically following bed planes in in the adjoining rock. Accompanying this, but distinct from it, is a thicker layer of quartz carrying some ore. The latter in some places is more than one foot in width. It is stated by a miner that the main slope continues sixty feet deeper, where it has encountered a well defined streak of galena.* This ore, as seen in quantity upon the dump, is chiefly very heavy galena occasionally carrying little patches of copper pyrites (chalcopyrite).

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*As I could not get down to this on account of the water in the shaft, it is impossible to vouch for the statement, but there is no reason for doubting it, while all the external evidences confirm it. The dump has much of the zinc ore from the 35 feet level, together with an abundance of remarkably pure galena in fragments, showing unmistakeably that it has come from a very similar environment.

Over the German shaft, so-called, there is a large, open building, well roofed, with a horse-power hoisting whim and a bucket. Good timbering and well laid runways with rollers are provided within the slope. The only adverse criticism that can be made of the work done is the course and dip given the excavation, but that may not be a serious matter. The probability is that the galena seam is wholly independent of the sphalerite layer, as far as exposed, and that the former is parallel to and underlying the latter. If so, a different method of working will be eventually demanded.

Whatever may be said of the Kellogg mining property as to its past, there is no doubt that it deserves thorough exploration, and, from present indications, it might be made to return much of the cost of development even now, if placed under the management of a competent mining engineer and metallurgist. Further remarks will be made concerning this district in Part II.

In the flat country between the ridges which skirt the Kellogg axis, as it may be termed, alluvial clays and sands prevail along the boundary line between sections 18 and 19, 3 N., 11 W., and between sections 13 and 24, 3 N., 12 W., but about the southwest quarter of section 14, in the latter township, crystalline quartz occurs along the road to Mineral P. O. This, at the surface, is rusty in streaks between the crystals and shows traces of foreign minerals. The southwestward extension of the Kellogg mine deposits should appear a little south of this, if they continue as far west. Prospecting in the southeastern portion of township 3 N., 12 W., would be based upon reasonable expectancy, to say the least.

The observations made along the line of the Fort Smith railway between Marche and Little Rock confirm the views expressed previously regarding the general structure, but the writer has had no opportunity to connect these results across the intervening country south and southwest of Little Rock.

South and southwest of Little Rock.—South and southwest of Little Rock the Fourche Mountains, trending N. E. by S. W., give good exposures of syenites, but, as the geology of these instrusive rocks is discussed in detail by Dr. Branner, reference to their geographic distribution only needs be made here on account of the possible relations of these rocks to the economic geology of the State. The northeastern limit of the outcrop of these syenites runs through the western edge of section 20, 1 N., 11 W., touching the southwest corner of section 17. Following this line we find it swinging westward through section 18 and into 12 W., diagonally across the south half of section 13, thence along the western edge of section 24, the south edge of section 23, crossing a branch of Fourche Bayou in section 22, thence via the north west corner of section 27. Here the line of outcrop appears to turn southeast across section 27 as far as the northeast quarter of section 34, whence it bears again southwest, but veers off eastward near the base line bending sharply to the north through the west half of section 35, and on via the southeast quarter of section 26 and the northwest quarter of section 25, then east across the south edge of the southwest quarter of section 24, and back to the starting point by way of 1 N., 11 W., sections 19 and 20. The present drainage follows very closely this outline. Upon all sides of the ridge of syenite, except its southwestern end, there are thick deposits of bright red earth, such as are abundant in the suburbs of Little Rock, and referred by the State Geologist to the tertiary and post-tertiary.

A problem of much interest in this connection is the history of an extensive outcrop of iron ore which follows very closely the eastern and southern limits of the whole igneous belt, as here defined. In the localities where the best exposures occur (sections 5 and 8, 1 S.. 13 W)., as well as at other points on sections 2 and 11, the evidences of decomposition are abundant, and the ore is associated or interstratified with a comparatively soft sandstone. All these facts and the occurrence of a considerable deposit of kaolinite crossing near the adjoining corners of sections 4, 5, 8 and 9, besides the nearly horizontal pos'tion of the non-igneous beds, seem to imply that the iron is a product of the tertiary age.

The ore itself cannot be discussed here, because not enough time could be given to its study to acquire an authoritative opinion concerning its economic value.* There is some reason for supposing that other masses of igneous rocks lie buried beneath this heavy tertiary and post-tertiary covering, for there are several outcrops of rocks more or less like those in the Fourche Mountain, in Saline and Hot Spring counties. A hematitic shale, described elsewhere, probably underlies much of the neighboring district, and this may have had more to do with the formation of the ore beds than is here suggested.

From Sweet Home to Wrightsville there are no rock exposures along the main road. Southwest of Sweet Home on the northeast quarter of section 36, 1 N., 12 W., there is a low ridge covered with coarse fragments of igneous rocks similar to those which occur in the Fourche Mountains, of which the ridge is really a spur. From this point southward as far as Wrightsville, on the northwest quarter of section 29, 1 S., 11 W., thence across country to Cockmon's (sections 17 and 20, 1 S., 12 W)., and northward nearly to the base line, nothing is exposed except yellow clays, with patches of red earth along the deep stream-cuts. Between Wrightsville and Cockmon's there is no deep cut, and the red earth is practically unexposed. Coming northward we discover the two causes which have made the red deposits a striking feature in the landscape. First, we cross the deep, canyon-like valley of a branch of Fish creek, which has cut down deeply into the lower formation; beyond this the course lies over ridges or mounds of slightly-inclined tertiary sandstones, enclosing the iron ore previously noted. Hence, as one approaches the Fourche Mountain dyke, the tertiary hills are seen to have been too much elevated for the more recent alluvium to obscure them; and, also, the still more recent fluviatile erosion has, in places, removed the alluvial capping. There is, too, a bluish clay, which appears to be more local in its distribution. This has probably been formed in much the same manner as the kaolinite near which it occurs, viz: by decomposition in place of one of the porphyries. This clay appears again with a quite similar environment upon the northern side of the Fourche Mountains.

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*These iron ores occur in considerable quantities in southern Pulaski and eastern Saline counties, and it is hoped that the Survey may be able at an early day to devote to them the attention to which they are entitled. Similar ores are profitably worked in other parts of the United States. A sample collected in Saline county near Alexander shows by assay, 58.4 per cent of iron and 0.095 per cent of phosphorus.—J. C. BRANNER.

Near the line between sections 4 and 9, 1 S., 12 W., at the school house, a shaft has been sunk and a small quantity of ore taken out. Another opening was made upon the iron-bearing deposit near the middle of the line between sections 28 and 27, 1 N., 12 W. Both of these are near the road. Some work was done also on the east side of the road near the line between sections 24 and 25, and Owen reports similar outcrops on sections 2 and 11, 1 S., 12 W.

In sections 26 and 27 the road crosses a bridge with a foundation of crystalline rocks covered by several feet of brown clay at its western end, in the surface of which, and more or less imbedded is a layer of water-worn fragments of the igneous series. This exposure is almost identical with that near Sweet Home already described. The small boulders which lie in an even layer over the southern slope of this ridge are much worn, although their composition does not suggest transportation from a distance. Wherever the writer has met the iron ores in the region of the Fourche Mountain dyke, there has invariably been the same general succession of deposits from the nucleal syenite outward to the alluvial yellow clays.

Starting at any point far enough distant, and making a section along a line which will cut directly across the Fourche Mountains, the following order will appear, in case none of the members have been wholly eroded:

1. Alluvial (more properly lacustrine) yellow and brown clays, gravels and boulders.
2. Red earth, lacustrine, unstratified.

3. Tertiary sandstones, soft, yellow overlying red sandstones.

4. Blue clay, kaolinite, etc., in places.

5. Porphyry, basic (iron-bearing minerals), basaltic, thinning N. E. Porphyry (siliceous) felsitic, etc., thinning S. W.

6. Iron ore, nodular, segregated, most abundant with basic porphyry overlying.

7. Massive, igneous rocks.

From the information obtainable thus far the above typical section appears to be the key to the geologic relations of many of the prominent iron ores within my district. This statement will not exclude even the magnetite and limonite deposits which occur under what appear to be quite different surface conditions, but we may leave the explanation until those ores are discussed in their proper order. In Franklin county iron ores have been seen which may not come under this category, but some of these are more closely related to the Pulaski county beds than would be evident at first sight.

West of Little Rock.—Going westward from Little Rock, on the Mt. Ida road, the black shales are well exposed in the deep cutting crossed by the wagon bridge. Here the dip is 50°, nearly N. (magnetic). Farther west quartz beds appear, thinning and swelling between layers of the shale, and these are followed by a thick quartzose formation, with quartz debris covering the hills. The road is laid out for a long distance upon these quartz ridges, lying back from the river, and skirting the valley of an ancient stream.

The country between the Hot Springs road and the Mt. Ida road is not very different from that which has just been described, except that it exhibits the natural effects of erosion in the streams which cross the road at intervals, and affords a better view of the rocks, more particularly of the shales, the tertiary deposits being absent from the higher levels. The dip is much increased in section 17, 1 N., 13 W., and turned a little to the east of north.

Hull's Slate Quarry,—In sections 16 and 17, 1 N., 13 W., the shales are indurated and have all the appearance of slate, even grained and black. In section 16, Mr. Hull has used this for roofing purposes upon his house. It has now been tested one year and appears to withstand the weather, but the reputation of that which was used in Little Rock some years ago is not so good.*

The Hull quarry, or the principal one, is in section 17, where much prospecting has been done. The available deposit does not seem to be very thick and much of the shale is so thoroughly laminated that it splits into plates which are extremely thin. In order to secure slabs suitable for use one must take such as are unlaminated, and these are too thick for the purpose. The places where the best pieces have been mined are all below the limit of surface weathering, and wherever atmospheric agencies have acted the slate is unfit for service. Well marked joint planes cross the stratification lines, cutting the shales into large blocks, but there is no cross-bedding.

There are no important exposures of solid rock along the main Hot Springs road within four and a half miles of Little Rock. The surface formation is mostly a light yellow clay, with occasional patches of red and yellow sands.

In the northeast quarter of the northeast quarter of section 20, 1 N., 13 W., a seam of ferruginous quartz, or a siliceous iron ore, crosses the Hot Springs road, but a short distance west of the Lawson (middle) road junction. The strike of the ore is nearly east-west. It is interesting because of the reported discovery of copper in a well in the neighborhood. The assay report in Table II, No. 2, shows that a small proportion of this metal is present, but it cannot be regarded as, in any sense, a copper ore.

On section 19, 1 N., 13 W., there is an outcrop of the black shale, dipping as before (10° N.). A quarter of a mile beyond this, on section 19, northwest quarter (?), the road turns northward through a natural cut, in which there is an exposure of about 50 feet in thickness of a tough, cloudy felsitic rock, slightly vesicular, with red linings to the minute crevice-like cavities. This undoubtedly overlies the black shale; it does not resemble igneous rocks in its weathering. Apparently it is overlain by the laminated sand-rock which forms a large part of the loose coating here. This runs into a kind of glistening schistose rock, which is very widespread over the region northeastward and southwestward, marking an horizon of some importance in the economic development of the country. In this vicinity some work has been done (July, 1888,) by prospectors in search of iron and manganese ores, but only a few pits and open cuts were excavated, without uncovering any noticeable deposit. The schistose formation may be regarded as basal, so far as the manganese layers are concerned, and it is, practically, useless to seek such accumulations below that horizon. East of section 19, 1 N., 13 W., the rocks are all below it, except where it is the surface formation, as in certain long, high ridges bordering the valley of Brodie's creek in section 17, etc. South of this, quartz hills, similar to those previously mentioned, but more broken, extend for miles in a general east-west course, and are completely covered with pebbles, boulders and imbedded masses of white to yellowish hues. From many observations farther west, I feel justified in regarding these outcrops as in place or nearly so, and as the representatives of one or more interpolated quartz beds. This subject will be discussed upon another page.

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*See Owen's Second Report, pp. 73-74.

The McRae Mine.—Section 30, 1 N., 13 W., has large areas covered by the quartz rocks and quartz debris, with associated shales. Not far from the middle of the southwest quarter of the section in low land, where the shales are covered with a thick deposit of greenish clay, in a situation topographically much like that of the Kellogg mine region, a large shaft was sunk and worked for a time. Three or four pits were also dug about a quarter of a mile east of this, and others south of these. In the large shaft a steam pump and hoisting apparatus were used. All openings are now filled with water and earth, so that but little can be learned of the contents of the workings from direct observations. The dumps show very little of any value. From samples shown by others and from gleanings in the earth about the shaft, small fragments of a peculiar fine-grained galena mixed with pyrites were obtained. These yield a little silver and lead by assay, but from all accounts the quantity taken out was very small. The ore has all the appearance of being imbedded in grains and nodular masses in the black shale, and the early abandonment of the explorations goes far to prove the barrenness of the deposit. However, this is a case in which no certain opinion can be given by mere inspection. A deposit like that of the Kellogg mine might exist here without discovery, except by just such explorations as have been made. One excavation, however, if well placed, properly executed, and carried well into the bed-rock, is as good as a dozen in determining the question.

CHAPTER II.

Pulaski County—Continued.

THE MANGANESE DISTRICT.*

Township I N., 14 W., is the present (1888) seat of the manganese mining in Pulaski county. The development has progressed so little that it will be impossible to do more here than to outline the area and to describe the principal workings. In a later chapter, in Part II, the relations of the deposits to others adjoining will be more clearly stated in connection with the discussion of the presumptive importance of the district as a mining centre. The boundary line of Saline county is crossed by this belt of ores so that further description will be necessary in chapter III. The direction of the strike over the whole belt is within a few degrees of east and west, the dip being nearly north, magnetic. Brodie's creek in its whole course lies east of the area which has been prospected, and a line drawn due west from the Fourche one mile above the mouth of this stream will pass along the southern edge of the ore tract, as it is now understood. The northern limit is not far from the north line of the southernmost tier of sections in township 2 N., ranges 14 and 15 W. This allowance of territory within Pulaski county is really much more than is usually claimed by those who have opened work upon the belt. As a rule, the miners have been guided more by the topography than the geology of the district, and this has led to a misunderstanding of the true situation. One company has emphasized this error in its published map, on which the manganese deposits are drawn with a decided N. W.-S. E. trend, somewhat in the course of the ridges and valleys of the region. The attempt to trace the beds upon the basis of such a theory has, in some cases, been apparently successful, but only because of the repetitions of the deposits. What are regarded as the direct continuations of the exposures in a given working are commonly the outcroppings of other parallel beds lying farther to the north or south. The best part of the area is barely three miles wide, but its length has not been clearly ascertained beyond the western boundary of Pulaski county. East of range 14 W., the rocks are, for the most part, so much obscured by later lacustrine, fluviatile, and alluvial accumulations that it is now impossible to state whether or not manganese ores lie beneath the surface. So far as the known structure is concerned, there seems to be no good reason why they should not extend eastward much beyond this district, but they would probably be found deeply buried under the thick detritus. The country rocks in which the ores occur are black shales and quartzose beds, the former below and the latter above, with the ore between, as an almost invariable rule; although the mineral is not infrequently found in pockets in the adjacent bed, especially in the quartz. The quartzose material is unlike much of that which occurs south of the manganese district along and south of the base line; it is more massive, containing some pure white, cloudy layers, but mainly thick beds of a tough gray rock, which often carries a high percentage of iron and manganese, being sometimes brown upon a newly fractured surface. The latter part of this description applies especially to the outcrops along the north and south edges of the belt, and the first portion to those interior areas in which the manganese deposits seem to be more regular and persistent.

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*The work done in this region, both in Pulaski and Saline counties, was practically all accomplished after the writer's passage through the tract in 1887. The descriptions here given are from special observations made in 1888 for the Geological Survey. In range 15 W., on the edge of Pulaski county, the facts collected were obtained while the writer was employed by Dr. W. E. Green, of Little Rock, through whose courtesy they are here recorded.

Beginning at the eastern end, the following are the important workings which merit mention:

"*Worthen's Diggings.*"—*As far east as the southwest quarter of section 19, 1 N., 13 W., R. W. Worthen has located claims upon some outcrops of the massive rocks containing segregations and uncertain layers of very pure, hard limonite, with similarly disposed bands of bluish, granular pyrolusite (manganese dioxide) running parallel with them at a little higher horizon. The best outcrop of the limonite seen (August 4, 1888,) was in one of the workings on the face of a high ridge and not in the best situation for development. Upon the other slope of the hill where the structure is better defined, the relations of the two ore bands can be made out more clearly, but development is needed to determine the amount and continuity of the deposits. From observations made in this part of the district, but at somewhat widely separated points, the conclusion is reached that there are variations of considerable moment in the quantity of the ore which can be mined, and that nothing but extensive exploration and development can reveal the positions of the "swells" in the so-called veins. In the southwest quarter of section 24, adjoining in range 14 W., some trench explorations have been made, which have uncovered streaks, or a concretionary network, of hard bluish pyrolusite, tending to follow the dip of a siliceous rock of brownish hue. The main rock has become gray and somewhat disintegrated, apparently from the segregation of the mineral. The dip of the country rock is 28° N., 7° W. The ridges in this region are long, high and precipitous. They follow neither dip nor strike in their courses, but trend approximately N. W. by S. E, and this feature has led to some blunders in tracing the ore masses. For the line of strike runs diagonally through one ridge and across the narrow valley to and through another, bearing nearly east and west, and so on. There is usually little chance to trace the beds where they cross the valleys; for the courses of the streams are such as to give only limited exposures at such places, while these are mostly covered with boulders and other surface accumulations. In section 30, 1 N., 13 W., about one mile north of Benton on the lower Hot Springs road, Mr. Worthen had considerable digging done in 1887 upon a thick surface deposit of ferruginous bog manganese mingled with manganiferous bog iron ore. Several pits were opened at the head of a ravine near where a former spring probably emerged. The material has not the appearance of a transported mass, but of an infiltrated product. The average character is earthy and not well assorted, but in some places the iron and manganese ores have been separately deposited. All over the ridges north of this point, the characteristic cloudy white quartz with black spots is visible, but the barren buff quartz beds appear only a short distance southward.

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*The Survey is indebted to Mr. R. W. Worthen, of Little Rock, for permission to use here the results of an examination made by the writer while employed by him in the summer of 1888. The references to the bog ore in section 30, 1 N., 13 W., are, however, based upon notes taken while engaged upon the Geological Survey, and these have not been previously reported in any form.

Chicago Shaft.—*The most extensive workings in the district, as late as August 1, 1888, were but a short distance from the trenches upon Mr. Worthen's property. The east-west mid-section line through section 24, 1 N., 14 W., runs between that and this, which is thus in the south half of the north-west quarter of the section. A shaft was sunk thirty-five feet upon an exposure of the white quartz between outcrops of black shales. The manganese ore occurs, as in similar cases, in an irregular layer beneath the quartz and above the shale, occasionally swelling out into large pockets. Much ferruginous sand or earthy iron ore, resembling the crumbled rock of Worthen's nearest diggings, and a considerable quantity of rich pyrolusite has been taken out. The manganese ore of best quality came from a massive pocket in the shale about twenty-five feet below the surface. The rocks dip N. 7° W., 30° to 35°, but the shaft was sunk vertically; hence it had gone down too far into the shale and the continuance of the ore-body was left in doubt. At this juncture work was stopped and a cross-cut tunnel running southward was started at the foot of the ridge.

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*Worked under option from the Capital Land and Mining Company.

The projector's estimate was that the manganese deposit would be cut at a depth of from sixty to eighty feet, at a point 150 feet from the mouth of the tunnel. This tunnel had been run about seventy-five feet when examined in 1888, but its grade was so steep that much of the calculated depth would have been lost before the intersection was made. In the valley of the creek, east of these workings, above the mouth of a little branch, there is a large deposit of bog ore and others of the kind occur at different points along the main creek. This particular exposure has much very pure pyrolusite, and from its situation and mode of occurence rough deductions may be made as to the probable high value of the unexplored belt directly west.

Capital Mining Co.'s Workings and others near Martindale.—In the northeast quarter of section 14. 1 N., 14 W., the Capital Land and Mining Company has taken advantage of an eligible location upon the upper Hot Springs road, to lay out the town site of Martindale in convenient proximity to several of the manganese diggings in which this corporation has been more or less interested. There is much difference in character in the several workings, but all which have shown any ore may be classed in the same categories as those already described

In the northeast quarter of section 14, upon the opposite flank of the ridge which rises just north of Martindale, the Capital Company has started a tunnel, which cross-cuts the strata. The situation, geologically, is something like the exposure at the Mozambique tunnel in Garland county (see chap. VII) except that the ferruginous streaks there developed are here only simulated by small pockets of ironstone concretions or decomposed pyrites, and the soft shales there observed redden more quickly upon exposure to the air. The Martindale shales are like fire-clay when wet, but they become hard upon drying. The dip is apparently local, as it does not agree with the general disposition of the rocks in the neighborhood, being 46°, N., 13° E., while the common dip is N. 7° W. Probably this irregularity is due to the displacement induced by the softening of the clay shale itself. Some bog ore occurs in the valley below this tunnel.

On the gap between this Martindale ridge and the next ridge east, upon the northwestern end of the latter, in the northwest quarter of section 13, there is an old opening* from which large masses of quartz containing a very good quality of pyrolusite has been extracted and thrown down the steep hillside. The ore occurs in pockets in the cloudy white quartz, and no evidence of a connected deposit could be discerned from the limited development.

On another branch of the Fourche crossing the northwest quarter of section 14 Messrs. Whittemore and Bunch have had some test pits sunk. The bog ores of iron and manganese cover a large part of the little valley of the branch, and in many places the manganese oxide is well concentrated, enabling one to separate it readily from the ferruginous ore, although this is not invariably the case. Over the surface hard fragments of pyrolusite are abundant, and the " wash " affords indications of some transportation from the northward. Probably the source of this material is in the quartzose ridges north of the little valley, and this idea is in keeping with the observations made farther west. A cutting upon the northern face of the hill which forms the south wall of the ravine has developed thin concretionary streaks similar to those described in the southwest quarter of section 24 (Worthen's), but these have been passed in the workings, as the bed containing them dips outward (northward) at the beginning of the cut, which bears southward. The rock which underlies the bog deposits is the black shale.

The Holly Spring Tract†—The upper Hot springs road crosses the west half of the northeast quarter of section 9, 1 N., 14 W., at the southern base of a long ridge running west towards Holly Spring. Through the whole length of this ridge there is exposed a thick bed of cloudy white quartz with manganese stain, accompanied by a layer of brownish sandy rock, with some intervening shale. A limonite iron ore of uncertain quality is more or less closely associated with the sand rock, and the quartz carries beneath it a persistent body of pyrolusite of excellent quality (see table of manganese determinations, Part II). This, which is above the iron ore in position, seems to improve and thicken westward as far as examined (about half a mile), but no work has been done upon it, and the observations are confined to surface indications. Apparently much material of this kind has been washed out of the quartz and shale, as many empty pockets occur, resembling in outline and character those which are now filled with ore. Masses of the clear pyrolusite, as much as six inches in thickness, weighing up to twenty pounds or more, may be picked up from the "wash" upon the hillside back of the school-house. Other proofs of the abstraction of ore by secondary action are visible in the large deposits of bog ore which have been made along the stream courses in the neighborhood. Some of these are not clean pyrolusite, but carry much iron, although there are patches of well concentrated manganese ore also. It is probable that the eastward extension of this ore belt runs through some of the ridges lying well to the north of those described in the preceding paragraphs as occurring in sections 13 and 14. The westward continuations are, as yet, unknown, but it is possible that the exposures along the southern edge of the adjoining tier of sections north, are really prolongations of these. A parallel outcrop, with somewhat similar characteristics, occurs in the ridge which starts west at the Holly Spring. This may possibly represent the same beds prolonged upward upon the dip, but a cursory examination does not leave that impression.

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*Claimed in 1888 by Whittemore & Bunch.

†The eastern portion of this area, near Holly Spring school-house, was examined for Dr. W. E. Green, who kindly permits the Survey to use the notes. The western portion had been previously examined, in 1888, for the Geological Survey.

Boyd's "Prospects."—The country through sections 7 and 8, 1 N., 14 W., is not generally favorable to mining operations, as the rocks are deeply covered by quartz debris and other transported material left as the relics of the ancient water course of the Fourche. Mr. J. L. Boyd, who lives near the middle of the east half of section 8, has made some tests by scattered diggings, which make it probable that the more eastern deposits extend through the northern part of section 8, at least, but the evidence is not very conclusive.

Martin and Smith Diggings.—A number of shallow pits and trenches have been excavated at different places in sections 5 and 6, 1 N., 14 W. In the southwest quarter of section 6, a little valley between two of the ridges has a large portion of its area covered with a thick deposit of bog ore, in which the iron and manganese oxides are more or less confusedly mingled; but the upper part of the ravine, and particularly towards the northern side, exposes a product which is much less contaminated with the iron ore. Openings have been made in several places, but no systematic mining work has been done. The ridge upon the south has, apparently, contributed the principal part of the ferruginous portion, while the manganese ore has come largely from the northern hills. It would seem that the little valley has been cut in the shales lying between the two parallel ore bands, whereas, in many other cases, both are running together in the same ridge. The south face of the southern ridge shows the iron ore predominating, as may be seen in a cut made in the southeast quarter of section 5. At this point, however, both kinds of ore occur and seem to be interbedded with the black shales, without any immediate connection with quartz layers. The iron ore here is a kind of clay ironstone.

Southward, across the main creek (not the main Fourche, however,) the manganese ore has been again exposed in another belt, in which the quartz shale contact is evident. The quantity of ore thus far brought to light is not large, the streaks in which it occurs being thin, but the quality is good. The most extensive workings in this tract are in the same quarter of section 5. These are known as Martin and Smith's "old diggings." The situation is unlike anything the writer has observed elsewhere, and so far as could be ascertained it is strictly local. The country rock is a soft grey shale, dipping

N. 7° W., from 38° to 42°, and the ore body has all the aspects of a vein filling a nearly vertical joint crevice, which trends N. 50° E. This vein is about three feet in width, and it is composed of iron and manganese oxides much like the bog deposits of the region, but more regular. Upon the whole the product is brownish, rather earthy, resembling beauxite, with certain streaks or pockets of purer limonite and pyrolusite. The material is more homogeneous and freer from grit and clay than most of the surface deposits. It probably represents at all points more nearly the average of the district product than any other known deposit, but it is less valuable than some, because it does not present the iron and manganese compounds separately as is often the case in the regular beds and the bogs.

Township 2 N., Range 15 W.—There are apparently two well marked belts of iron and manganese ores, which run near the boundary between Pulaski and Saline counties, where it crosses range 15 W., on the line between townships 1 and 2 N. Each of these belts has two distinct bands of quartz or quartzose rock, separated by shaly beds, and the iron ore invariably follows the lower siliceous bed, the manganese ore being always associated with the upper one. The more southern belt is so near the boundary, that its outcrops are visible upon both sides of the line, sometime in one county and at others in the adjoining county. The more northern belt is almost exactly half a mile distant, and its exposures occur also upon both sides of the mid-section line across the southern tier of sections in 2 N., 15 W. For obvious reasons, both tracts will be described in this place.

The farm of M. O. Sutton, in the northeast quarter of the northwest quarter of section 1, 1 N., 15 W., is so situated as to receive the " wash " from several of the neighboring ridges. At points in the fields, south, east and west of the house there are heavy deposits of bog ores of iron and maganese. These all lie in the direct line of the drainage courses, and they seem to have been formed by a kind of leaching process The best manganese ore is obtained from the westernmost exposure, which is nearest to the natural outcrops of the primary deposits. In the ridge north of the house, and mostly in Pulaski county, the double-banded ore deposits appear, the lower bed being a compact reddish brown limonite, not very thick, and more or less cemented to the quartzose sand-rock. The upper, or manganese band is thicker, and not much different from similar outcrops eastward, which have been described. The continuation of this deposit has been reported in the northwest corner of section 2, 1 N., 15 W., and near the middle of the northern edge of this section there is a sandstone or grit with a network of manganese segregations cementing the mass into the semblance of a conglomerate. The same structure in all respects was observed in the southwest quarter of the southwest quarter of section 34, 2 N., 15 W., so near the township line that a part of the outcrop is in section 3, 1 N., 15 W. Some of the manganese ore is very rich, and fragments of considerable size can be obtained, but the deposits have not been developed and consequently they are of uncertain value. The tough reddish brown iron ore crops out below the manganese, as at Sutton's. The strike of the beds is not coincident with the trend of the ridge, but it is more nearly so than in some cases. Indications of the extension of this belt are visible in the southeast quarter of the southeast quarter of section 33, 2 N., 15 W., near a large chalybeate spring which emerges in the bed of a stream.

The outcrops through the middle of the southern tier of sections in township 2 N., 15 W., are much like those in the boundary belt, so far as the ore is concerned, but the quartzose layers are more decided grits and sandstones and the ridges are usually higher and longer. Without more development, it is impossible to form a reliable opinion regarding the amount of iron or manganese which can be mined over this area. The surface indications are rather meager, and there are more signs here of concretionary action, or of the segregation of the ore from the adjoining quartzose rock. In the southeast quarter of the northeast quarter of section 35, near a chalybeate spring there is much bog manganese, and in the southwest quarter of the northwest quarter of the same section, fragments of harder and purer ore occur in the "float," as if from outcrops near. The same features were observed in section 34, southwest quarter of the northeast quarter, where the concretionary network of manganese ore closely simulates a conglomerate by binding together irregular masses of the grits and sandstones.

A third belt still farther north may be represented by exposures in the northeast quarter of the northeast quarter of section 35. In a small cave or large pocket in massive quartz, there is much of the manganese stain, with the appearance of mineral having been washed out, and a considerable quantity of manganese ore is in the float along the hillsides below. This belt of quartz was not followed a great distance upon the strike.

The dips taken vary somewhat in amount, from 27° to 42°, but the strike is fairly constant, usually within a few degrees of eastwest. In a very few cases the dip was almost exactly north.

Slates in the Manganese District.—The shales through the south half of section 34, 2 N., 15 W., dip 27° N. White's slate quarry is situated in the southwest quarter of the southwest quarter of this section. The beds which are worked at this place may be readily traced across the country eastward, and they have been more or less developed at several points. Near the south line of section 35, at Mooney's, the exposures are far better for working, as the stream has there cross-cut them in the line of dip. At White's the dip is 27°, at Mooney's it is 38°, due north in both places.

White's quarry is said to have produced a considerable amount of roofing slate which has been shipped to St. Louis and elsewhere. The owners claim a ready sale for it. The slabs are tough and easily shaped, and the supply is great, if practical use proves the durability of the product. The method of mining is rather expensive and wasteful. A large, vertical, square opening, like a huge shaft, has been made and the thin black shales are removed as carefully as may be convenient from above and below thick shaly beds which have to be blasted away. The cost of hoisting an excessive proportion of waste, and the liability of destroying a large amount of the material sought for profit, must soon dictate more skillful and economic methods of exploitation. The situation is not the best for this purpose, and there is so much of the shale in the region that more favorable exposures will enable other quarries to compete with this in the market.

From 1 N., 13 W., continuing westward into 1 N., 14 W., in a somewhat tortuous course through sections 25, 26, 23, 22, 21, 28, the road for several miles passes over successive ridges of the white quartz mentioned as occurring on section 19, 1 N., 13 W., with occasional flat, but narrow tracts, where the little side streams have cut deep enough to reach the shale. But there are very few exposures of this shale, for the quartz pebbles and quartz sand, with finely comminuted grit-rock of darker hue, have covered the surface almost completely. Farther on, there is some good soil in the bottom lands, but for miles at a time the roads leading westward are necessarily laid out over the barren quartz hills. At the crossing of Panther creek, in the northeast quarter of section 28, there is a high bluff upon the right bank, with thinly laminated sand-rock overlying a thick section, which shades off gradually downward from a sandy, yellow and brittle shale to a jet black one. Climbing the ridge and going southward the white quartz again appears on the surface as far as Josh. Snow's.

Following out one of the sand-rock ridges to the west for a mile or more, one comes to a place where the erosion has laid bare the underlying sandy shales. The character of the drainage here is peculiar , bearing some resemblance to the effects produced by hot springs, but with little tangible evidence of the positions of the ancient springs themselves, if such there were. The hint of such former action is, however, enough to cause one accustomed to such signs to study the locality more closely. Mr. Snow had directed me to the place to examine some iron ore deposits known as the "Fletcher diggings." After some fruitless search for these, and while looking about for possible traces of the springs, I was rewarded by discovering in the yellow shales, near their junction with the sand-rock, not only a few obliterated pits or depressions such as are commonly formed by hot springs, but also the iron ore which had been sought. This ore occurs in just the situations where the long extinct hot springs must have emerged. It differs from that heretofore described in being very compact in texture, but with a tendency to a structure which is common in the "pipe-ore" of Pennsylvania. It gives a yellow streak when scratched, and is, therefore, limonite, although many wrongly regard it as magnetite or lodestone. Its color is very dark brown, almost black, and it carries a high percentage of manganese. It is probable that other outcrops might be discovered in this region by diligent prospecting, but not much has yet been uncovered. The few small opening here have mostly been found by burning the trees so as to clear the ground for digging. No deep holes have been necessary, but the ore is not well exposed and the soil must be stripped off before it can be reached. The locality referred to is in section 29 or 30, 1 N., 14 W.

Going north across Panther creek, a fine exposure is visible in the bed of the stream, showing the black shale underlying the sand-rock, not directly, but with the yellow sandy shales intervening. The alluvial tracts are broader here than farther east, owing to the turned up edges of the shales, which in other places are uncovered only by the denudation of the overlying hard rocks.

CHAPTER III.

Saline County.

The outcrops of iron and manganese near the boundary between Saline and Pulaski counties, in range 15 W., have been described in the preceeding chapter. [*]Fron the indications [illegible] of Sutton's house, in the northeast quarter of the [illegible] quarter of section 1, 1 N., 15 W., there seems to be [illegible] discovering similar deposits in that direction also. [illegible] from observations made east of this in Pulaski [illegible] that a very promising belt of manganese ore runs [illegible] south half of the northernmost tier of sections in township 1 N., 15 W. In the northwest corner of section 2, [illegible] in the bed of the stream and in adjacent banks, [illegible] interbedded with ordinary black shales and slaty [illegible] it. The grits seem to overlie the quartz, [illegible] some serpentine and traces of other minerals, [illegible] and azurite (?) (copper carbonate). The quartz [illegible] but the enclosed minerals, including the serpen- [illegible] disseminated. Southward from Sutton's, and [illegible] the black shales with quartz beds are very [illegible] and there is no reason to believe that the geologic [illegible] different from what it was found to be [illegible] of sections in township 1 N., 14 W. [illegible] therefore, the great manganese belt of Pulaski [illegible] this region also. The peculiar white [illegible] stains, similar to that observed in town- [illegible] W., occurs also across much of those portions of township 1 N., 15 W., which should possess them if the several belts be prolong westward along their strike.*

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[*] [illegible] this region in 1887 to 1888, the objects in view did [illegible] manganese belts, hence the evidence necessary to set- [illegible] points has not been obtained. The suggestions given [illegible] upon geologic structure.

There is some very interesting structure yet to be worked out in ranges 14 and 15 W., in Saline county. It would be hazardous to attempt a full explanation of this structure without more complete observations than have been made thus far, but enough is already known to give an outline of the situation. The north dip does not change in going west until a north-south line running through the middle of range 15 W. Here a change occurs, which has been noticed in a number of places north and south of the base line. There are cross folds which bear about N., 13° E., the effects of which upon the topography are described in this chapter.

The eastermost axis appears to practically cut off the manganese tract, and in connection with it there is a fault of much economic importance. There are at least two classes of minerals which have been deposited or modified by causes directly connected with this structure. The Magnet Cove area is closely linked in its history with the development of these axes of upheavel. Going southward along the eastern flank of these folds the Pulaski county structure continues for the most part unbroken until the Saline river drainage is reached north of the base line, and south of this the same features extend farther west, but with more complication, as new axes appear whose trends conform more nearly to the strike of the manganese belts. Through section 12, 1 N , 15 W., the manganese stained quartz is abundant, as near Burr's, Smith's, and elsewhere.

In the southern half of section 11, on the upper Hot Springs road, at a point where one of the manganese belts might be expected to come out in the extended line of strike of the Pulaski outcrops, some quartz was noticed, having manganiferous limonite associated with it, much in the same way as in the manganese area; but near this and overlying it, a ledge of talcose shale is exposed in a little stream. As far as could be made out, the strike is the same as in the adjoining county eastward, i. e. nearly east-west. The exposure is not good and it has not been traced, there being much alluvial earth in the region. Apparently, though doubtfully, the seam is intercalated with black shales, not regularly between the strata, but inclined at a much lower angle than the dip of the country rock. It may be, however, that the country rocks dip, less here than estimated. In the northwest quarter of section 13 there are two openings, or, quarries, in rocks which carry serpentine and steatite (soapstone). The quality is rather gritty at the surface, but it might be valuable for some purposes. The country is flat at this point, and the material in question cannot be mined with the greatest economy, as it is almost in the bed of the Fourche, which rises near this point. The rocks seem to have been altered by the action of forces developed in connection with the uplift not far west of the outcrops, and presumably the exposures nearer the fault will prove more impor ant. Black shales overlain by quartz are above the soapstone, which appears to be conformable with them, the dip being less than 30° in the shales and nearly 80° in the soapstone.

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*See "Township 2 N., Range 15 W.," under "The Manganese District," in Chapter I.

A very significant feature of the geologic section, as exemplified in various places over the whole manganese and soapstone areas, is the occurrence of one rock which may be taken as a landmark by prospectors. This is the slabby sand-rock before mentioned, a rather tough, shiny rock, which gives a ringing, metallic sound when struck with the hammer. A rather wide belt of this runs between the manganese and iron tract upon the north, and the iron and manganiferous tract upon the south. A repetition of the rock, or one like it, forms a narrow belt between the main manganese area and the conglomeritic red sandstone manganiferous tract which overlies it.

The broad sand-rock belt which was reported in section 19, township 1 N., 14 W., and northward extends into Saline county nearly along the same tiers of sections, bearing a little south of west. This stage is wholly above the soapstone, as far as my observations go, and speaking generally, the products south of this line are rather manganiferous iron than manganese ores.

In the southwest quarter of section 11, 1 N., 15 W., on the upper Hot Springs road, there is an outcrop of quartz in a position very similar to that reported as occurring near the impure soapstone in section 13. Very neary the southwest corner of section 11, almost due west of the latter outcrop, and below or within the black shales which underlie the quartz, a steatitic rock appears directly in the road. This is apparently of better quality than that seen in section 13, but it has not been tested. It can be traced a short distance westward. In the southeast quarter of the southeast quarter of section 10, the dip of the black shales is 25° N., 77° W. Near the center of the north half of section 15, the same rocks dip about 30° towards the north. The structure hereabout is rather confused and requires more careful study.

Wallis's Soapstone Quarry.—South of the Hot Springs road, in the northeast quarter of section 15, 1 N., 15 W., there is a hill which has been cut through in such manner as to leave a narrow gorge. The rocks which compose the elevation are largely the slabby sand-rock and other tough beds, but behind these exposures upon the south is a good development of the soapstone in a favorable situation for mining, at least at the start. There is a dip of 80° in the soapstone, which has a width of more than twenty feet, if the deductions from the observations be correct. From its position the mineral has the appearance of a huge banded vein, but there is reason to assign its origin to a rolling movement along the fault line which is evident here The deposit deserves to be thoroughly tested. Notwithstanding the imperfect work which has already been done, considerable amount of very choice material has been taken out, but the development has not well proven the future capabilities of the mine. Much of the soapstone is of inferior quality for use in large pieces, but by proper assorting it may, perhaps, be graded so as to pay fair returns upon the cost of working. However, there are as yet insufficient data upon which to calculate quantitative results.

Slates.—About a quarter of a mile beyond the soapstone outcrop. an exposure of black shales occurs near the road, upon the left bank of Hurricane creek, where the dip is only 18° S., 77° E. These rocks are hard and some of them thin enough for slating purposes. Prominent joints cross the beds in a course approximately northwest by southeast, and another set at a right angle is less distinct and regular. This structure will be of much service in mining operations, if the material is of marketable value. Another digging on the east fork of Cane creek in section 16 has exposed similar slaty shales.

The dip is 30° N., 77° W., in black shale through a part of section 16, but changes again to N., 7° W., in section 18, continuing thus westward for some miles.

Through sections 24, 25, 26 and 27, 1 N., 15 W., the shale areas are prominent with ridges of quartz intervening. Without going into minute details, it may be stated that the greater part of this region is uninhabited, and that much of it promises but little for agricultural purposes other than fruit growing. The soil is thin, and the quartz debris is widely scattered over it. Upon the ridges the timber is rather sparse, though excellent in size and quality. There is much more of it upon the shale belts, but only along the stream valleys does the underbrush grow luxuriantly, and there is very little grass. The geological structure of this section is as simple as that of the southwestern part of Pulaski county. The roads follow as closely as possible the strike of the shales, but there are several thick intercalated beds of hard quartz in the series, which form ridges between these bands of low lands, so that there are here four routes across the area within three miles, all bearing towards the same point beyond.

The influence of the quartz is very marked, for there is no evidence of any stratum of it more than a very few feet in thickness, yet it seems to have resisted eroding agents with the utmost facility. The western extension of one or more of the southernmost beds of manganese ore in Pulaski county may be represented in this section, but no work has been done upon them, and there are no important deposits of the bog ore, as far as is known. The black shales constitute a comprehensive group; but it is impossible in a rapid survey to systematise them properly, when, as in this case, quite similar rocks occur in a considerable variety of associations. The following conclusions, however, have been worked out: (1) That there is a certain place in the series, presumably near the base, in which a thick stratum of very black shales comes in; and (2), that quartz partings are frequent in the middle portion, giving way to sandy shales and finally to sand-rock above. This classification does not include the whole of the shale group; the proper basis for the arrangement of the lower members must be sought farther west and farther south. In crossing Saline county from Pulaski, on the road to Whitmore's, the gritty sand-rock is passed on the divide between the waters of the Saline and the Arkansas rivers, nearly upon the county line. Descending westward to the North Fork of the Saline river, we get the reverse section, running down partly through the quartz beds before reaching Cane creek. As upon the Fourche drainage, the alternation of shale and quartz have had a great influence upon the amount and character of the erosion. But unlike what is observed in that district, here the streams cut across the strike following the shale troughs only on the minor bends, and then usually not directly. The cause of this peculiarity is not very apparent here, but some structural features occurring plainly in the next township afford sufficient explanation of its origin. Upon section 34, 1 N., 16 W., the black shales dip 30° N., 77° W. The significance of this, taken in connection with other facts to be reported later, and with the uplift represented by Fourche Mountain, as well as the character of the drainage south of this region, is much greater than will be recognized at first sight. There is undoubtedly a key here to the geology of a wide area adjoining. Unfortunately, I was compelled to move too rapidly to work out the problems presented in a thorough manner. There is probably a low fold, or a series of folds, extending nearly at a right angle to the strike of the formation previously described. Even the courses of the Ouachita and the Arkansas rivers north and south of this district show sudden changes, which imply some such uplit, and the same dips have been observed in the region of Magnet Cove along the same line. Excellent sections of the black shales are afforded by the deep cut gorges of the north fork of the Saline river, especially in sections 30 and 31, 1 N., 15 W. In sections 29 and 30, the "middle road" passes over high and long ridges of quartz and sand-rock, but it descends to the valley of the north fork beyond the great bend, to a belt of shale and alluvium.

Iron Ore.—The iron ores which lie south of the slabby sand-rock in Pulaski county, as at the "Fletcher diggings," continue westward into Saline county and more of them probably lie southward in 1 S., 14 and 15 W. In the southwest quarter of section 13, 1 N., 15 W., on the Lawson, or middle Hot Springs road, there is much white quartz to which considerable iron ore is attached. A prominent belt of this runs east and west as the continuation of one of the lines of outcrop which is the cause of a ridge in the southern edge of Pulaski county. This lies very close below the slabby sand-rock which crops out through the same tier of sections eastward and westward. Some search was made here for the soapstone, but it was not discovered, although the topography is such as to indicate a possible continuation of the conditions at Wallis's quarry as far east as this. Prospecting for iron, manganese and soapstone over this area would be far more reasonable than very much that has been done without returns in some parts of the state.

Between the base line and Benton are folds with axes bearing east-west. A small one occurs in the south half of section 30, 1 S., 15 W., and a larger one, with a fault, bears across the northern part of the same tier of sections. This is clearly exposed in section 33.

[illegible] In the northeast quarter of the northeast quarter of section 33, 1 S., 15 W., claims which lie in part

along the fault noticed in the preceding paragraph have been worked for nickel. They are laid out upon comparatively high ground upon the east bank of Saline river. Half a dozen shafts have been sunk in different places, but the best developments thus far have been in the western portion of the property near the mouth of a small branch. One shaft (No. 1), is at the edge of the stream near a sharp bend, and this is only three and a half feet below the water level. Shaft No. 2 is not more than twenty feet from this, but it has been cut down through the bank of the creek to nearly the same level, so that it is twenty-seven feet in depth. A little below the dump level of shaft No. 1, a short tunnel or stoping has been cut to connect this pit with shaft No. 1. Upon another terrace, some 30 feet above the surface level of shaft No. 2, and 85 feet east of the latter, shaft No. 3 has been sunk to the depth of 43 feet. Both north and south dips appear in the exposures in the walls of the canyon near the mine, and the structure seems to be that of a faulted anticline. In the mine workings the black shale and quartz dip N. 7° W., 65°. In the bluffs just north of the lower workings, the section is confused, but the southward dip is apparent, with some crowding in of the strata upon a false dip, as if the faulting had produced an irregular "slip." The quartz has every indication of being interbedded in the black shales. It has a thickness of 2½ feet. In shafts 1 and 2 it has been practically cut through. A slope of 65° northward (magnetic) will be required to follow it properly. This rock is more or less laminated and partially "honeycombed." A considerable quantity of iron oxide has been deposited in crevices and pockets and much of this is associated with a whitish or greenish powder, which, upon examination, proves to be copperas, or ferrous sulphate. In shaft No. 3, where the rocks are much above water level the principal ores are pyrite, marcasite and allied minerals. The quantity is not very great, as far as developed, there being no large, well defined streaks. The ore in the other shafts is different, although the conditions there are such as to show that it is simply a remnant or alteration of very similar deposits. Millerite (nickel sulphide), in fine silky, dull yellow fibres, and in leathery flakes and leaf-like masses partly fill the otherwise exhausted cavities, and this mineral also occurs in the crevices between laminæ of the quartz, often with iron minerals. The discussion of the formation of these substances, as they now are, and the prospects of the mine as a nickel producer, will be more fully discussed in Part II, under the appropriate heading (see chaps. x, xx). This occurrence of millerite is certainly a very interesting one, and it would seem that further development is warranted.

In section 35, 1 N., 16 W., quartz debris and quartz sand, with black and sandy yellow shales, crop out, forming bluffs at a little distance from the river. Red soil obscures the other formations at intervals. The Perryville road is crossed at the summit of one of the hills, and soon after the underlying black shales appear in section 34. Other exposures of the shale occur in sections 34 and 33, with the N. S. strike (N. 13° E.) as before. Quartz "float" is more or less abundant over the whole area. The divide between the North Fork and Alum Fork, on and near the base line, in range 16, exposes the tough, cloudy quartz referred to on page 12, or at least a rock quite like it, and occupying a similar relation to the underlying formations. Alum Fork, at the crossing (section 6, 1 S., 16 W.), has no rock exposures, but the black shales beneath the quartz series are visible to the east at the base of the bluffs, and the road passes over a broad alluvial valley with frequent quagmires, representing a horizon presumably identical with that reported on upper Panther creek, in Pulaski county.

The black shales appear again in a branch along which the road passes, a quarter of a mile beyond Alum Fork. Going up this creek, another higher exposure occurs about a mile beyond at the ford, the rock gradually changing westward to contorted siliceous shales, and soon afterwards the quartz beds again become prominent. These last are associated with the cloudy quartz, which in places is almost black, and above this gray quartzites are occssionally met, the different members being separated by shale partings of unequal thickness. Turning north at the cross-roads on the southeast quarter of section 1, 1 S., 17 W., the Blocher road goes down rapidly through that portion of the shale group which carries the quartz beds, and then passes over a shale valley which bends a few degrees to the east of north. Near the middle of this valley the stream has cut down to red hematitic shales, which are in all respects similar to the outcrop near Rock creek, in Pulaski county. The section beyond is much like that seen in passing between Rock creek and Bangford's, but it is all crowded into half a mile.

West of the "Sulphur Spring" which is near the top of a low ridge in the eastern edge of section 2, the hematitic shales, much reddened, are again uncovered in the valley of Alum Fork, beneath black shales, which themselves underlie the quartose formation at the spring.

The western dip continues to Mrs. Bradfield's in the northeast quarter of section 5, 1 S., 17 W. About one hundred yards north of Mrs. Bradfield's house, almost upon the base line, there are some small outcrops of limonite ore, much decomposed near the surface. In position it is above the black shale, or within that formation, and beneath the sand-rock, which, however, has been eroded just at this point. The situation, geologically speaking, is almost identical with the outcrops of manganiferous limonite described under the name of "Fletcher diggings" on page 34, except that the ore is more earthy at Mrs. Bradfield's, and seems to carry less manganese. It is highly probable that the source of the iron in both places is the hematite shales which are buried under them, and that the deposits were both made by chalybeate springs. The evidences of the former existence of hot springs on the Bradfield tract are also noticeable, but perhaps less so than in the "Fletcher diggings."

This deposit of limonite is interesting as having been the cause of some excitement in June, 1887, on account of the reported discovery of gold and silver in it. The samples collected (see No. 12, Table 1, at end of Part II.) yielded traces of gold and silver but they are not to be regarded as averages of the deposit, having been taken as random specimens. A very similar deposit in the neighborhood (No. 13, Table 1) yielded nothing. I was informed by Mr. J. L. Bradfield that Mr. Samuel Aughey reported gold $2.50 and silver $12.50 in specimens assayed by him. This, upon the basis of calculation usually adopted in the Hot Springs region*, would not be a profitable ore to work, except under very favorable conditions. with a heavy demand for the iron ore as a flux, these deposits, provided that they do carry gold and silver, might possibly find a remunerative market.

Following up the Alum Fork from Mrs. Bradfield's, four miles north, crossing sections 32, 29, 20 and 19, to Cedar creek, on section 18, 1 N., 17 W., the same succession of rocks is encountered, without getting above the black shales with intercalated quartz beds. This conveys some idea of the great thickness of the quartz bearing group. The dip gradually veers towards the north along this route. In section 20, near the mouth of a little stream flowing south into Alum Fork, one of the quartz beds crosses the road on its strike, (nearly E.-W.), the dip being N. 7° W. This is either an extension of Blocher lode or of a parallel bed. It carries a small amount of serpentine. The results of assays will be found in Table 1, No. 13. In the eastern half of section 18, Cedar creek exposes the black shales, which dip 39° N. 7° W.

In the bed of the stream prospecting has been done upon a few exposures of thin white quartz beds, but with no results worth noticing here. A mining claim has been located upon the croppings under the title of the Eureka lode. (See Table 1, No. 14).

The road from Perryville to Blocher, after crossing the Alum Fork at the mouth of Cedar creek, passes southward over ridges of the quartz-bearing shale group, and finally across a low mountain capped with the sand-rock, and down the other steep side to the broad shale valley in which Blocher P. O., (Robert's place), is situated. Interesting sections are afforded by the cuttings made for the road along the hillsides. At the base of the ridge on the southern slope, half a mile north of Blocher, is a light gravelly deposit held together by an abundant ferruginous cement. This has the appearance of an old hot spring deposit. Its geologic relations are similar to the Bradfield iron ore, which it resembles in many particulars.

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*$20.00 per ounce for gold, and $1.00 per ounce for silver.

Across the road from the house at Blocher, a small pond was dug in the alluvium. In one spot there was found a very finely powdered black earth, which forms a soft slime with water. This is the material of the treacherous quagmire, and it seems to be best explained by regarding it as a relic of former hot springs.*

The surface indications in the shape of depressions, special deposits and peculiar drainage, are abundant enough to convince one who has given close attention to the phenomena and products of existing thermal springs, that this explanation is correct.

Besides the deposits of iron sinter half a mile north, there is another of much greater importance about the same distance south of west from this point, directly upon the main road. At the crossing of the stream, a fine chalybeate spring may be seen a few rods above, upon the opposite bank. This issues directly from a platform or flat mound of iron cement covering many square yards. The main formation below it is black shale. But this is a very small exposure compared with the thick deposit of the same material which lies in the road a short distance beyond upon the same side of the stream. Mr. Phil. Bradfield gives information of other accumulations of a similar character within short distances. These are all akin to the limonite ores previously noted, and they seem to have nearly equivalent relations to the hematite shales lying beneath, but not in juxtaposition with them. This, however, is as far as it will be wise to generalize without more intimate knowledge; especially is caution necessary in view of the fact that so many widely separated outcrops agree so closely in their horizon.* The quartzite layers have resisted erosion more successfully than the quartz beds, being less brittle, hence the ridges in this section are veritable mountains, although the main valleys are wider than any along our route hitherto. This is due both to the soft nature of the underlying shales and to the dip of the quartzites which cover the northern slopes. Fine examples of this, as well as the protective resistance of the tough quartzites in a diagonal cut across the strike, are to be seen in sections 35, 34, 33, 1 N., 18 W. These rocks are there traversed by occasional small quartz seams or veins, which are more or less coarsely crystalline.

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*In the Yellowstone Park, Wyoming, many of the active hot springs, especially mud springs, are now working up the sands and clays in their caldrons to an almost impalpable powder. In certain districts in Arkansas the result of such action upon siliceous material is no less marked; but with such shales as occur in parts of the series now under review, we should naturally expect just what is here described.

The Sand Carbonate Mine.—Turning westward near the base line in range 18, and following the Cedar Glades road a a short distance, one strikes a steep trail leading over a prominent quartzite ridge, covered with loose fragments of the same material. The hill is about 150 feet in height, and more precipitous upon the western flank, which walls in the valley of the middle fork of Saline river. Not far below the summit, the trail ends at the head of a ravine, which has been cut out by some action more powerful than can be accredited to existing agencies. There is evidence, too, that the source of the supply of water was near the crest of the ridge. To an eye accustomed to the drainage contours of a region of active thermal springs, the explanation is not far to seek. Undoubtedly there was, at one time, in this spot, a very copious hot spring. Closer examination shows that the subterranean channel occupied, practically, a zone of transition between the black shales below and the quartzite which caps the ridge. Beneath the shales other hard strata crop out, then more shale, and so on, indefinitely. But for some reason not apparent without more extended study in the field, this particular horizon became the escape valve for the heated waters, and these eventually filled up the conduit with the deposits which are now being worked as the Sand Carbonate mine. In one sense this deposit is a banded vein, with two pairs of layers, but it is not a "fissure vein," as that term is ordinarily understood. It is more properly considered a "contact" deposit, and yet such an explanation is not wholly applicable; for, in reality, the filling of the vein space partakes chiefly of the nature of a bedded accumulation, and the probability is that all, or a large part, of the material has been simply transformed in place from pre-existing shales and siliceous layers. The deposit consists of four distict seams, the whole being covered at the outcrop, and, as far as the vein has been explored, with a thick stratum of the quartzite. The dip of the whole is 40°, bearing a few degrees north of east, there being no unconformability between the vein and its enclosing rocks. In descending order, the following is the section:

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*[illegible] and Hot Spring [illegible]

1.	Tough, gray quartzite, heavily bedded	15	feet.
2.	Yellowish, red, sandy earth	10	..
3.	White quartz, somewhat rusty	2	...
4.	Quartz, similar to No. 3	2½	...
5.	Red and white sand, siliceous sinter; white clay with rusty and black quartz, in patches and pockets; the sand and clay irregularly mixed, with blotches or nodules of the same interspersed much as the pebbles in a conglomerate	5	feet.
6.	Black shale, which is yellow until exposed, say	25	...

The developments upon this property, July 11, 1887, consisted of a slope, 260 feet in length, which had been excavated in the lowest layer (No. 5), and partly in the overlying quartz. For the first 100 feet or more the workmen closely followed the vein on the dip of 40°, keeping well up in the quartz; then the pitch was increased to 45° for about the same distance and afterward changed to 48°, which carried the drift down into the shales and left the deposit overhead. A shaft was then sunk 25 feet in the underlying shale. A chamber was also cut out above, exposing the vein. The collections from this mine were very complete, and the results of assays appear in Table I, Nos. 15 to 17 inclusive. The Sand Carbonate is located upon the southwest quarter of section 33, 1 N., 18 W.

An examination of the white sand of No. 5, in the laboratory, shows that it is the weathered product of a true siliceous sinter. Thus far it has not been possible for a complete analysis to be made of this material, but it is probably pealite. The sand itself is milky white, with yellow and reddish spots, lightly coherent, but usually each small lump has a nut-like nucleus of hard, porous sinter of a dull grayish hue. This interior portion has a hardness of 6.5, and, like the sand, gives with the blowpipe no reactions except for silica and water.

Taking the Hot Springs road at its junction with the Cedar Glades road in 1 S., 18 W., and going southward, we pass over the black and yellow shales in the creek valleys, with the quartzites and altered sand-rock in the ridges. The dip is 40° to 45°, apparently a few degrees west of north all the way, until after crossing the Saline county boundary near the southwest corner of section 6. Here we are upon hills of quartzites and intercalated shales, which suggest by their uncertain outcrops that they have a steeper dip, though it is not readily made out in such exposures as are afforded.

CHAPTER IV.

Garland County—Northeastern Portion, Including Hot Springs.

Along a line running diagonally from northeast to southwest, through sections 20, 29 and 32, 1 S., 18 W., there is a marked change from the aspect of the country northward, although the hills continue through the north line of section 32. Descending to the north branch of the South Fork of Saline river and ascending to the divide between this creek and the main South Fork, there is a noticeable absence of the harder beds. We have passed down in the geologic section to the sandy shales beneath the sand-rock and to the black shales below these. The quartz-bearing shale series does not appear as prominent as it is in Pulaski and Saline counties, which may be explained by the fact that the members exposed here are somewhat above the horizon of those previously described; for the South Fork and its tributaries have not cut down very deeply into the black shales. The cause of this is the peculiar change in the amount and direction of the dip over the area drained by these streams. At a spring on the left of the road, directly in the north branch of the South Fork, the black shales dip S. 7° E., 20°. The erosion has, consequently, been of a different type from that previously considered. The shale valleys are broader in places, and the quartzite hills are more irregular and less dependent upon geologic structure for their forms.

From section 12, 2 S., 19 W., to Hot Springs there is very much to interest the geologist. In crossing the divide between the South Fork of the Saline and the head-waters of Gulpher creek, in section 14, 2 S., 19 W., there is a large amount of fragmental quartzitic material scattered over the surface as if deposited by some heavy current. This is intimately associated with red and yellow earths. Beyond this there is a thick deposit of red earth, not unlike the tertiary detrital accumulations at Little Rock. The whole aspect of the geology within a certain area hereabouts is a close imitation of the Pulaski county section, barring the igneous exposures. The big chalybeate spring, on Little Gulpher creek, is both confirmative of what is less apparent before reaching it and prophetic of what soon appears beyond, for there is reason for regarding this interesting bowl as an extinct thermal spring.

The shales and quartzitic strata continue to crop out for half a mile, when the road ascends to the water-shed between Little Gulpher creek and the sources of Hot Springs creek. Just below the summit the road has been blasted out through a quartzite, which may, perhaps, have been deposited from subterranean hot water drawing mineral supplies from the horizon of the hematite shale, which is presumably beneath us at this point. A few rods off the road to the east is a deposit of very fine grained quartzite, upon which whetstone quarries have been opened. The dip is not very different from that previously reported, but just over the summit the surface rock is a thick stratum of whitish, flinty quartzite, or novaculite, dipping over 70° S., 27° E. The change is decidedly abrupt, with a well defined crevice and all the indications of a fault at the junction. Further evidence concerning the extent and direction of this fault will be given elsewhere in this report, but there is considerable support to the opinion that the course of the dislocation is north of west and south of east, and that it is rather limited, both horizontally and vertically.* The topography upon all sides of this locality is remarkably interesting, perhaps unparalled in the world. There are places in the Yellowstone Park which resemble it in the peculiar results of erosion, but they cannot be closely compared with it, owing to the totally different character of the rocks.

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*The following facts seem to require the interpretation here offered: 1st. The change in dip from about S. 7° E., to S. 27° E., occurs in several places northwest and southeast of Hot Springs, along a line N. 40° W., by S. 40° E., approximately, through the locality here described. 2nd. At all these points the topography changes, and the rocks differ upon opposite sides of the line. 3rd. The change is always within the range of one group of rocks.

In Garland county the line of this supposed fault is characterized by peculiar topographic features and by a remarkable development of hot spring deposits. The existing thermal springs are confined to a very limited area, and they are not only very inconsiderable, as compared with those which are now extinct, but they do not occupy the positions of the greatest activity in the past. The relics of hot springs are far more numerous and very much more prominent in other sections than they are in the immediate vicinity of the city of Hot Springs. The great fault itself was but a mere accident in a history of important earth movements, and it was probably one of the latest of these effects. The basis for these statements will become more apparent as we proceed.

West and north of where the fault crosses the Hot Springs road, there is a very interesting locality in which the hot spring relics are exposed chiefly through human agency. This is on the northwest corner of section 28, 2 S., 19 W. On relatively very high ground, near the summit of Sugar Loaf Mountain, there is a heavy deposit of gravel and other water-worn material, for which no adequate explanation is discernible in the topography, and it is only by the study of a number of scattered "prospect" holes that the underlying structure can be fully made out.

The Glenpatrick Lodes.—J. T. McKown has made three locations under the name of the Glenpatrick lodes, upon the northwest quarter of the northwest quarter of section 28, 2 S., 19 W., and on these he has made half a dozen or more openings, several of which were examined:

No. 1. "Bertie's," a 20 foot shaft, showing 4 feet of ferruginous cement, underlain by a thick deposit of clay, the strata dipping southeast 55°

No. 2. The "Nickel Plate," a quarter of a mile east of "Bertie's," consists of two cuttings, or long shallow shafts, exposing tough quartz at the top, siliceous sinter between this and the schists, and tough quartz below all. Dip 34°, N. 57° W.

No. 3. "Patsy's Pride," 200 yards southwest of the "Nickel Plate," is a small shaft 15 feet deep, in quartzose rock. The dip is northwest and nearly vertical.

No. 4. The "Bowen," is half way between "Patsy's Pride" and the "Nickel Plate." This is a cutting and shaft with tough quartz near the top, and siliceous sinter in layers, arranged in the shape of a dome dipping away on all sides.

No. 5. The "Monarch," is 150 yards west of the "Nickel Plate." It is a long channel stripped off and exposing ferruginous cement and quartz rock. The dip is S. 27° E.

The results of assays of the collections made here are given in Table I., Nos. 19 to 23.

No. 1 and No. 3 are probably examples of the opposite sides of a syncline. At No. 4 both dips are also apparent at one end of the cutting, the side corresponding to No. 3 being even more nearly vertical than the latter. No. 5, which is upon the slope of the syncline corresponding to No. 1, has, like it, the ordinary dip south of the fault line before defined. No. 2 has a purely local dip, and No. 4 shows conclusively that a hot spring or geyser has at one time emerged from its position; for, besides the dome already mentioned, with its successively deposited layers, an excavation made in the centre of this mound has struck an old passage now filled with soft material. No. 1 has been the site of an ancient spring, but of the type illustrated by the Sand Carbonate mine, where stratification planes have provided the subterranean passages, and the adjacent rocks have been largely altered in place. The dip in No. 2 and the character of the rocks also imply similar action, although the development has not been such as to lay bare the old mound. The most remarkable fact is the extent to which the process of obliteration by fluviatile or lacustrine deposition has been carried. There has been a large amount of erosion even at this altitude, and it seems evident that the conditions have been very much changed since the faulting of the strata, though the local deposits were probably made at a comparatively recent period.

The Active Hot Springs.—All the active thermal springs of this region are grouped in a narrow belt in section 33, 2 S., 19 W., being nearly all upon the United States reservation. Being charged with other duties, the writer's study of these has thus far been limited to such a simple review as was essential to acquiring a knowledge of the structure and geologic history of the district under consideration. It will be proper to briefly consider now the relations of these existing springs to the very abundant relics of those which are extinct, and to determine the causes and results of their emergence in this locality.

These bowls, as the hot caldrons may be termed, are not numerous, and, as compared with many in the Yellowstone Park in Wyoming, none of them are very large. They differ also from those in the almost perfect uniformity of discharge, quantitatively considered. In temperature they do not agree closely among themselves, and the maximum is less than is often the case in the National Park. The composition of the water is as nearly like that of the average Yellowstone tranquil spring as the nature of the rocks will admit. The deposits which are a prominent characteristic in that region, are lacking here, but this difference is less real than many suppose, for it simply signifies that the Arkansas pools are in *statu quo*, whereas those in Wyoming are continually subject to irregular fluctuations. The water does not boil over the edges intermittently, so as to furnish thin films of liquid, which deposit solid matter by evaporation. That this process would go on here under circumstances equivalent to those in northwestern Wyoming, is proven by the growth of a ferruginous and siliceous incrustation about the borders of an old spring below the government free bath-house, where requisite conditions formerly existed. It should be remembered, however, that waters of this class do not commonly deposit solid matter by simply cooling, but by evaporation. This explains the absence of any considerable coating upon the tubs in the bath-houses and upon the banks of the streams, and also the fact that such coating is rapidly formed when the water is allowed to run slowly along a wooden trough.

There are some bowls of extinct springs, which have been active within comparatively recent times, situated well up the Hot Springs Mountain, but those which are now flowing are near the base of the ridge. This implies that the water pressure or the heat supply is diminishing, and the same thing is shown by the occurrence of much older relics near the summit of Sugar Loaf Mountain and elsewhere in this vicinity, usually at greater altitudes. That the ancient springs were vigorous enough in some cases to eject the liquid is proven by the layered sinter (pealite) which forms the dome discovered in opening No. 4 upon the Glenpatrick lodes, and by similar evidences in other localities. But, if we carry out this line of argument, step by step, to its logical conclusion, using the facts as we meet them in the field, there is no possible way to account for the present order of things upon the supposition that the existing hot springs are of contemporaneous origin with the extinct bowls, for in that case they must have produced much more extensive deposits. The structure is such, nevertheless, as to make it probable that the ancient and existing hot springs have drawn their supply of water from a common source.

It should be stated that the great fault previously referred to appears to have its "downthrow" upon the northern side. This causes the lower rocks to appear at the surface upon the southern, or "upthrow" side. If this view be correct, we may justly regard the tough siliceous beds as representatives of that portion of the shale formation which, farther north, carries the interpolated quartz beds. We are certainly above this horizon north of the fault, and the succession of the strata south of the break is quite similar to what may be observed wherever good exposures occur in the quartz hills, save in one particular. The hard beds here are not simple quartz, but flinty rock, a product which would result from the alteration of quartz in place, by the action of highly heated water. Any other possible source of such material could not, by any means, have furnished deposits of the same character as these, which occupy a vast area in beds of great thickness occurring with extreme regularity. Owen took the same view, or a similar one, of the origin of these "novaculites," as he termed them.*

It is an interesting fact that the thermal waters have not been able to force a passage through the shales, except to a very limited degree. As the joints in these rocks are rarely regular and continuous, there has been no path open, except along these planes of stratification; and even these have not served as conduits for the water until wedged apart and filled by other material. In brief, although it is very difficult to explain all the facts, I think there is some evidence that the original quartz was not a simple aqueous product, formed and deposited under the usual conditions. The reasons for this view may be deduced from what follows in these pages, but it should be noted here that the junction of the unaltered quartz with the shale is almost invariably marked by a semi-fusion of the adjacent rock and the occurrence of a thin layer of some refractory mineral, not a product of solution, which adheres strongly to the quartz and fills the depressions in its rough surface.

The tough, compact, siliceous rocks in the ridges about the city of Hot Springs are regularly bedded, interpolated among the black shales, and they continue for many miles across the country westward. These have all the indications of having been altered in place from a stock like the brittle quartz beds

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*The theory here advanced to explain the origin of the novaculites—that they are metamorphosed quartz beds or sandstones—has long been accepted without question. I feel confident, however, that the compact varieties of novaculite usually known as "Arkansas stone," have been produced, not from sandstones or quartz, but *by the metamorphism of chert.* The reasons for this opinion cannot be given here in detail, but, briefly stated, they are: I. The stratigraphic position of the novaculites of western central Arkansas, which is the same as that of the subcarboniferous chert or flint beds north of the Boston Mountains. II. The similarity of the gross structure of the two deposits. III. The composition of the two rocks, the chert having its silica in an amorphous state, the metamorphism of which has produced the compact and very finely crystalline condition of the novaculite. A chapter upon this subject appears in volume IV of this report. JOHN C. BRANNER.

northward, by the action of very hot waters which could permeate them, but could not permeate their enclosing shales. This will explain the occurrence of the numerous individual hot springs, relics of which occur over a wide area of the country southward and westward. It sufficiently accounts for an almost unlimited number of variations in the character of the deposits, and it furnishes a reason for the existence of each particular product in a restricted region of its own. All the observed features afford evidence of the correctness of this opinion, but the most important fact—the regularity, continuity, and wide distribution of this altered quartz—must have required some special cause. To learn what this has been we must first inquire whether there are any similar formations connected directly with these; and, if there are, what other relations exist among them which are not essentially characteristic of the scattered relics. Investigation will show that the fully altered, infiltrated quartzites are produced only in situations where three conditions prevail, viz: first, the quartz predominates over the shale; second, the enclosing shale is very compact and not well stratified; and third, the formation has been tilted at a high angle, and is usually nearly vertical. These requirements are realized most completely when, as at Hot Springs and other localities, the thick quartz stratum lies in the trough of a narrow fold.

The City of Hot Springs.—In the northwestern portion of the city of Hot Springs, a short distance back of the horse-car stables, on the Mt. Ida road, the black shales overlying the altered quartz crop out, exposing a good section with a steep dip, S. 27° E. At short intervals in small crevices, chiefly bed planes in the shales, there are thin seams of pyrites associated with quartz. To the eye, there is no striking difference between any two layers of the shale, but some portions seem less tough and more lustrous than others. The surfaces of the shiny layers are coated with thin plates of graphite.

The locality, in its every feature, geologically considered, offers no inducement to the miner or prospector, unless the pyrites be auriferous. A shaft of considerable size, (ten feet by ten feet), has been sunk through the gravel down to the shale, to a depth of twenty feet or more. If continued in a vertical direction it will very gradually go down through the shales, probably exposing an indefinite number of streaks of the pyrites. Thus far there is no sign of any important deposit; the locators claim, however, that lead has been discovered in certain of the shaly layers, which are more or less friable, and which, when wet, form a graphitic "black mud."* The samples taken here have been carefully assayed and otherwise chemically tested, and there is no trace of lead in the deposits. The shale is an ordinary anhydrous aluminium silicate, or hardened clay, giving but a slight reaction for iron. Exceedingly thin seams of quartz, very irregular and barely noticeable, traverse minute lamination planes in the dark gray shale, and thicker seams of rather pure graphite, or plumbago, equally incrust two sides of a layer removed from the mass. It is this mineral, mixed with the shale, which, when the deposit is sufficiently soft, makes the "black mud" of this locality. As to the probability of the finding of gold and silver at this point, there is very little indeed, unless metals be contained in certain other insignificant bands of pyrites, which also occur in alternation with the shales and the graphite. The results of assays given in Table 1, No. 27, is a fair indication of what the average of such portions will yield.

The graphite and the pyrite, by their composition and their environment, show that they are the products of local alteration, and that they have not been subjected to the action of important hot springs, although the pyritous layers are often associated with quartz. The bulk of the formation is made up of the shales and graphite, chiefly the former.

The stream from Whittington cove passes down Whittington Avenue through a synclinal trough, and joining the Park

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*The terms "black mud," "blue mud," "red mud," etc., are favorite Arkansas names, given originally by certain assayers to soft, earthy substances in which they claim to have discovered gold, silver or lead in considerable quantities. As far as can be learned, the appellation "black mud" properly designates a product of the Ozark mine, in Montgomery county, but the name is bestowed upon any wet black shale, or other rock, which will produce a coherent mud when squeezed in the hand.

Avenue stream, has cut through the southern wall of solid quartzite, which has a steep dip, 70° to 80° N., 27° W. Below these are more shales alternating with other quartzites and shales until the contrary dip is reached, and pass again through a reversed section after coming out of the gorge in which the hot springs and bath houses are situated.

West Mountain is part of a huge anticline, the rocks upon the southern slope dipping S. 27°, E. from 35° to 45°. At Hot Springs the end of the ridge upon the south side has been extensively denuded and a large territory to the south has been similarly eroded. Hot Springs Mountain drops off more gradually, and it has been considerably modified by more recent hot spring action. This gives a different character to the topography eastward, and determines, in a large measure, the present drainage course of Hot Springs creek.

CHAPTER V.

Garland County—Continued. Southeastern Portion.

All over the region to the southeast, and over most of the country to the southwest there are thick accumulations of detritus which have been laid down since the wearing away of a number of ridges parallel to the Hot Springs anticline. These old denuded folds, which were once nearly or quite buried by these deposits, have again been partially exposed by the scouring action of the streams upon them, and in this way the ancient topography is repeated to some extent, though the present ridges run diagonally across the old folds. Following the Benton road east from Hot Springs for about eighteen miles, to section 24, 2 S., 17 W., beyond the mouth of Pleasant Run there are no important exposures which differ from those which have already been described. The ancient topography is much obscured by recent detritus and the road follows the strike, only occasionally cutting across the folds without including a wide range of the tilted rocks.

The surface contours, and the nature of the present drainage through the basin of Gulpher creek, all lend force to the opinion that the ancient water-shed was materially changed by the great fault previously reported, and that the main Gulpher, as well as the lower portion of its west branch, are approximately following the course of the fault itself. In further support of this view the dips along the Benton road are in three or more directions, corresponding to those elsewhere observed. From Hot Springs to the west branch of Gulpher creek only the steep dip (N., 27° W.,) of the Hot Springs Mountain was observed, though a reverse dip, with the same strike, probably occurs not far to the south of the road, and it may possibly be passed over where the surface formation obscures it. In the valley of the east branch, and farther east in range 17, the strike (dip chiefly N., 7° W.,) corresponds closely with that observed on the Blocher road just north of the fault line. Between these points, about on the divide between the east branch of Gulpher creek and Ten Mile creek, which is a tributary to the south fork of Saline river, is a transverse fold bearing about N., 13° E. The dips near the east line of Garland county also indicate the extension of the parallel fold observed in Saline county west of the Perryville road.

Practically the same structure is revealed by an examination of the country southward, along the Malvern road between Hot Springs and Magnet Cove. Going eastward from Hot Springs, the road runs several miles upon the northern slope of what may be called the Hot Springs anticline, then it crosses other folds diagonally, following near the water-shed between Hot Springs creek and the Gulpher. This divide is not a fold, but an eroded ridge formed by the leveling down of parallel folds and the later change of drainage by the fault, which has left a series of hard beds upon the upthrow side. The dips will indicate the number of folds represented, but these are all so steep that but little can he made out from them in a hasty trip. A subsequent study of the exposures in the valley of Hot Springs creek has, however, cleared up many doubtful points.

The idea of the extension of the fault line in the course of Gulpher creek below the forks appears more justifiable the more the facts are reviewed. At the crossing of this stream on the Malvern road, there is a strong contrast in the topography of the opposite sides of the valley, which cannot be explained in any other way.

Only a short distance east of the crossing of Gulpher creek, a western dip (N. 77° W.) is encountered, followed by the reverse dip farther east. The anticline thus outlined is apparently the prolongation of the great fold which has been traced from the Sand Carbonate mine in Saline county to this point. The Ouachita river, after cutting through this fold to its eastern border, turns northward along its strike until it joins the Gulpher and follows its course in a sudden bend, both being apparently guided by the fault. The parallel fold which was crossed in Saline county east of this one, also extends to this latitude and probably much farther. No data were obtained for determining whether the fault extends beyond this eastern fold; I am inclined to the opinion that it does not, but that the disturbance originated near this region, and that the fault itself was due to the stress induced in the rocks by two or three systems of folds emanating from some area near Magnet Cove.* This district must occupy a whole season's work of the Geological Survey, and nothing more than general conclusions can be drawn until a thorough topographic survey has been completed.

A little southwest of Lawrence the road crosses a ridge in which there is an exposure of hard rocks dipping N. 77° W., followed by the black shales. Around Lawrence there is a limited area of chocolate colored earth, forming a low plateau.† It is difficult to make out a section through this region, owing to the extensive erosion and subsequent deposition of detritus; but, in general terms, it may be said that the rocks become more granitic eastward showing vertical exposures, and finally the dip is reversed in section 18, 3 S., 18 W.

The Potash Sulphur Springs.—Dr. J. T. Fairchild has an extensive sanitarium near the head of a little ravine, on the northwest quarter of section 17, 3 S., 18 W. The water used for medicinal purposes exudes from the rocks very slowly, and is collected by setting a heavy earthen pipe down vertically to a depth of from 2 to 5 feet, and cementing its lower edge securely so that the water will enter only at the bottom.‡ The overlying rock at this point is granitic and contains minute specks of black mica and some organic matter, the base being composed of albite and anorthite. This layer softens when wet, and the springs appear to be in it; but the underlying formation, a felsitic porphyry, probably yields the saline ingredients. Farther down the creek a rock is exposed much like the granite described above, and apparently overlying it. This is reddish and seems to differ from the lower layer in a replacement of albite by orthoclase. Organic matter is also more abundant. The dip of all these rocks is 35° and upwards, S. 77° E., corresponding closely to that observed farther north.

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*It is possible that a fault has occurred in connection with the Blocher-Gulpher uplift, but the only suggestion of it in the field was in connection with the topography of the region of the Sand Carbonate mine.

†A similar but local deposit in equivalent topographic relations to the surrounding country occurs a few miles south of Waldron, in Scott county.

‡For an analysis of the water of Potash Sulphur spring, see Vol. IV of the Annual Report of the Geological Survey for 1888, under "Mineral Waters."

Dr. Fairchild states that in running the line between sections 17 and 18, the needle was deflected strongly to the east in going west of the line, decreasing rapidly as the surveyor moved east of the line. This is an interesting fact, and may possibly indicate the existence of a magnetic bed west of the line in section 18.

The key to much of the geology of Arkansas is confined to a small area in this region. Being the center of the disturbances, and the seat of activity, a very considerable part of the dynamic history of the State may have to be explained by reference to a district comprising only fifty square miles in the southeastern corner of Garland county and the adjacent portion of Hot Spring county. The Garland county share does not include more than fifteen square miles, however. Its further study will doubtless prove important, for it includes granitic exposures which very probably are associated with earlier rocks than have been recognized elsewhere in such connection.

From Potash Sulphur Springs down to the southeast corner of section 17, the dip continues S. 77° E., or thereabouts. The change in the strike to that of the formations northeastward in Saline and Pulaski counties is not very well shown along the Malvern road, being apparently obscured by the detrital formations, of which the red tertiary earths and gravels constitute a large portion. But near the middle of the south line of section 15, 3 S., 18 W., there is a recurrence of the dip

S. 7° E., very steep, in black shales which are harder and tougher than in most exposures previously noted. The section east of this, including hard quartzites, indurated clay, ironstone, etc., soon goes beyond the line of Garland county and into the interesting precincts of Magnet Cove.*

From Hot Springs southward to the county line, passing down Hot Springs creek from the city, the dip of N. 27° W., is immediately reversed, the southern side of the anticline revealing black shales and thin dark gray felsites unlike the rocks northward. The angle of dip increases southward, being greatest in the quartzites, as if the nearness of the Gulpher fault had produced a kind of overlap, or a sliding upon the bed planes. This section corresponds to the southern slope of West Mountain, but includes more strata, some of the beds of that ridge not being well exposed here. Near the middle of the north half of section 9, 3 S., 19 W., the dark quartzites are nearly vertical, but still dip S. 2° E. They are well exposed upon the left bank of the creek in a section 300 feet in thickness. At the upper end of the outcrop there is a seam of soft, dark brown granite about two feet in thickness, studded with jet black hexagonal crystals of mica (biotite), half an inch wide. The base of the rock is friable and easily weathered, so that its position in the cliffs is only marked by its debris, but the seam is cut through in excavating for the city sewer opposite this point, and the stream has also exposed it in the bottom of a trench or pool formed by its rapid wear. This granite is met with in other places, always with the same associations and with the same dip as the adjacent rocks.

Soon after this we cross a syncline, then an anticlinal fold near the line between sections 9 and 16, then another syncline, and a third anticlinal ridge near the south line of section 16. It seems probable that a fourth fold comes in across sections 28 and 29, but the structure is much obscured and it will require considerable labor to map its course from direct tracing.

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*It has been considered best to classify this part of the report geographically by counties, hence we now proceed westward, leaving the eastward continuation of this region for discussion elsewhere under the head of "Hot Spring County."

The occurrence of a dip of S. 27° E., at the Ouachita river in section 28 and a dip of 60° N., 27° W., at the ford on section 29, and on section 36, 3 S., 20 W., leaves but little doubt upon the subject, however. I failed to make out this structure upon the Malvern road, which follows the water-shed, but it is readily discernible along the lower middle and Arkadelphia roads, and with some difficulty also upon the upper, or Amity road. The Hot Springs railway gives a section which includes a number of the folds.

At Roulston's ford of the Ouachita river in the southeast quarter of section 28, 3 S., 19 W., the dip is nearly vertical, S. 27° E., and the stream is coursing diagonally down the dip, but soon turns into the strike. A short distance below the ford, upon the right bank of the river, Mr. J. T. Roulston showed me an outcrop of the biotite granite already mentioned. Here it is underlain by dark gray quartzite and overlain by a somewhat fissile, tough greywacke.

South of the Ouachita river the country is heavily timbered, but the surface is rugged and the soil light, especially towards the east. Judging from observations made farther west, two or more folds should appear between the river and the south line of Garland county, but they cannot be readily made out, except at intervals. The area lying between White Oak creek and Cooper creek is a particularly unfortunate district in these respects, and, in the southern portion, the geology is still further obscured by fallen timber. The old hurricane belt of 1881 is a desolate region, difficult to cross, and somewhat confusing in its uncertain exposures. But the difficulty may be overcome in some degree by a comparison with the surrounding country, and by using the few straggling records which nature has left in this tract. The most striking feature is the very high angle of the dip, which is S. 27° E., in almost every recorded observation. These observations were not numerous enough to clearly define the strike of the beds, but the general succession of strata is so much like that farther west, that I have no doubt of the existence here of the same series of folds.

CHAPTER VI.

Garland County Continued.—Southwestern Portion.

The Trap Mountains.—About the middle of the east half of section 3, 4 S., 19 W., just south of the core of granitic and associated rocks, there is a series of ridges more or less strictly parallel, the rocks dipping S., 27° E. In some respects these ridges recall the mountains about the city of Hot Springs. Like them, they are made of quartzose rocks, more or less altered by hot spring action, with intervening shales; but they differ in important particulars. In a measure they are similar to that class of ridges which is typified by the Sand Carbonate mine, but there are other characteristics not to be found elsewhere, although these deposits extend indefinitely east and west from this little area. The nearest approach to them which I have seen outside of this belt, is in Saline county near Blocher, but those accumulations were upon an insignificant scale as compared with these.

The transition from the granitic area is made through a belt of sandstones and quartzites, cropping out in a low ridge. South of this there is a series of steep ridges running diagonally across the strike of the formations. These constitute the great chain known as the Trap Mountains, which extend westward from this point many miles, with but few gaps, and those not directly across the ridge. There are six ranges, each one of which is broken at intervals, but in such a manner that the ends of the ridges overlap each other. Erosion has largely obliterated the elevations at certain localities, but the chain is complete for fifteen miles along the southern boundary of Garland county.*

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*This is the eastern end of a more or less continuous range of mountains which crosses the State in a nearly east-west direction, and passes into Indian Territory in southern Polk county. For the purposes of geographic and geologic discussion I have called it the Ouachita mountain system.—J. C. Branner.

The Ouachita river swings southward as it bends around the northeastern end of the mountain, and in township 4 S., 19 W., the ridges are high and steep, being separated by narrow gorges cut in the softer rocks by the small side branches of Cooper and White Oak creeks. But the principal streams and their larger tributaries, flowing northward to meet the river, have cut the outlying ridges into short lengths. The dip of the rocks being within a few degrees of vertical (80° S., 27° E.) good exposures occur only at the summits of these "backbone" divides, unless one follows the streams which cut across them.

By both these methods some good sections were compiled in Garland county. The number of folds must be made out by crossing the whole series, which would take one well down into Hot Spring county. This was done farther west, where the greater portion of the Trap Mountain chain lies south of the county line. In range 19, north of the line, there are several ridges, but they are all erosion relics, due to the denudation of intervening shales. In the first ridge known as East Mountain, the rocks are quartzose, dipping about 85° S., 27° E., with white sandstone beneath and quartz on top, separated by a persistent layer of manganiferous iron ore, two feet thick, which seems to be cemented upon both sides to the adjacent rock. There are three varities of this ore, viz: 1. Siliceous, sintery and vesicular, somewhat like a conglomerate. 2. Compact, dark, banded ore containing a large percentage of manganese. 3. Sandy or earthy limonite, with a very small percentage of manganese.

The second ridge, which is separated from East Mountain by a narrow valley cut out of the black shale, has similar outcrops of cemented ferruginous material, excepting that the deposit lies upon the north side of the mountain, joined to layers of siliceous sinter above and below, while the main mass of the ridge is composed of altered quartz-rock like that of West Mountain at Hot Springs. The sintery walls of the iron ore bed were not apparent at the west end of East Mountain, where collections were made, but in passing around the eastern face the whole structure is visible, with the sinter upon both sides of the ore, as in the second ridge. This last, on its northern slope, is scored by ravines at frequent intervals, which alternate with narrow promontories, each little gulch starting abruptly from the hillside, after the manner of the stream channels which carry off the water from the hot springs in many places in the Yellowstone Park. I can conceive of nothing but hot spring action to account for such topography, and not a few other indications of such action may be detected all through this region. On the head waters of Cooper creek, in section 12, 4 S., 19 W., the effects of such activity are very marked indeed, and in a few instances, the remnants of the ancient bowls are still discernible.

It is a very significant fact that such desultory work as has been undertaken in mining has been almost wholly confined, so far as this area is concerned, to those localities in which there is reason to believe hot springs have formerly existed. The results of assays of samples taken at different points appear in Table 1.

The Grand Mazarn Basin.—The northernmost ridge of the Trap Mountains crosses the boundary line between Garland and Hot Spring counties just west of range 20. What is known locally as North Mountain lies mostly within Garland county, and Rush fork cuts it in two on section 8, 4 S., 20 W. Some red sandstones crop out along the county line in the western portion of range 21, the dip being about 60° S., 29° E. Throughout the region north of the Trap Mountains denudation has been extensive, and the nature of the topography suggests that the work has been done by some ancient westward-flowing stream. On section 11, 4 S., 22 W., soft, yellow, red and white sandstones occur in an exposure in a cliff on the bank of a small stream. Slabby sandstones and quartzitic rocks overlie these farther south, the dip being 65°. Several pits have been sunk upon the flanks of low ridges in this section, ostensibly for mining purposes. An erroneous notion is popular in Arkansas that soft, red, sandy formations are the most favorable for the discovery of gold and silver. Almost every deposit of this nature is regarded as a "sand carbonate" ore charged with the precious metals. It is a fact, however, which any geologist who reads this report will at once appreciate, that in such material is about the worst place to seek profit. There are vast accumulations of this nature in the State, which have been formed under conditions precluding all probability of gold and silver deposition in any form. There may be some cases in which the circumstances were more favorable, but these are almost invariably so distinctive in character that there is little danger that they will be overlooked.

In the southwestern part of Garland county there is a walling-in tendency, the country to the west gradually becoming more diversified and mountainous; but the lower valleys of the Little Mazarn and Mazarn creek are silted extensively with sands, clays and gravels. Occasionally one can make out very fair sections of quite limited extent, but although these confirm, in a general way, the observations made elsewhere, it would not be safe to draw structural conclusions from them without a more thorough survey.

This great Mazarn basin or denuded tract, covering an area of nearly one hundred square miles, partly surrounded as it is by mountain ridges, would be very difficult to understand from a study of topography and structure only, but it is easily explained by a reference to the localized action of the forces which have altered the strata upon the north and south; or, perhaps, we should say that the existing features have been due to the absence of such effects in restricted localities. This style of denudation is not uncommon through this portion of Arkansas, by reason of the peculiar geological history.

There is a large part of this tract which has not yet been fully explored by the Geological Survey; hence it would be unsafe to generalize more freely upon this particular basin, although I have completely skirted it and carefully studied the greater part of the surrounding country.

The Hot Springs and Sugar Loaf Anticlines.—The ridges which hem in the Mazarn basin upon the northwest are the outliers of those which must claim a large share of our attention in the chief mining district of Montgomery county. In the southern part of Garland county the axis of the Hot Springs anticline follows closely the upper course of the Little Mazarn through sections 4, 8 and 7, 4 S., 21 W.; and the parallel fold to the northwest, which was traced through the area of the Glenpatrick lodes, Sugar Loaf Mountain and West Mountain, near Hot Springs, is probably represented here by an axis of elevation bearing S. 63° W., which passes out of Garland county very near its southwestern corner If this view be correct, the Big Mazarn is running about upon the strike through the middle of section 18, 3 S,, 20 W., and the Ouachita river crosses the Hot Springs fold in section 8. The general course of Bull creek at the ford on the Bear City road from Hot Springs must be nearly parallel with this axis, and almost upon it.

This and its compeer, the Sugar Loaf anticline, are not so prominent west of the Ouachita river as they are between it and Hot Springs. In a preliminary survey, it is impossible to unravel completely the structure of an intricate section, and one must often be content to get just enough insight to make the known facts seem confusing. This, I confess, is my own attitude with regard to some problems presented by these ridges where they are cut by the fault. Such results as have been reached are deduced from observations made over a wide field; hence they can be more clearly announced in another chapter, when considering the geologic history of the whol- region traversed. Several mining claims have been located upon the southeastern slope of West Mountain, between Bull creek and Hot Springs. Those examined are described below.

Wikel's Pyrite Deposit.—In a gulch tributary to Bull creek, on the southwest quarter of the northeast quarter of section 2, 3 S., 20 W., Felix Wikel has done some work upon a remarkable exposure of pyrite and quartzite, which occur in a vein-like body and occupy the position of an interstratified bed. Overlying all are the black shales with a layer of the quartz, beneath which is an irregular mass of siliceous sinter, including the pyrite in thin seams and in solid bands, one of which is sixteen inches thick, as well, as in pockets of varying dimensions. Underlying this more or less directly is a kind of cement rock, or hot spring conglomerate, which is abundant in this region. Still lower come in thick beds of a fine grained, somewhat massive, gray shale, which is itself underlain by a hard and pyritous black shale. This pyritous shale is called ore by the owner of the claim. In cuts made farther north and nearer the summit of the fold, this indurated bed has a soft, white shale directly overlying it. The dip of the series is 38° S., 27° E. Assays of samples taken here are recorded in Table 1, Nos. 44 and 45.

Quartz Lode—On the southeast quarter of the northwest quarter of section 1, 3 S., 20 W., a location has been made in quartz rock dipping 35° S., 27° E. There is an outcrop of some twelve feet in all, in three well defined beds, three, four and five feet, respectively, in thickness. The lower bed is of tough and massive quartz, the uppermost of the same material, though more brittle and rusty, while the intervening stratum is made up of three attached layers of siliceous ironstone, or ferruginous quartz-rock, the structure being shown by weathering and by non-continuous jointage planes across the bedding.

The Shippey Mine.—At the eastern end of West Mountain, north of Jonestown, a suburb of the city of Hot Springs, extending from the reservation line westward, the Shippey mine is opened in rocks nearer the axis of the fold than the preceding properties. Here the dip is 60° to 65° S., 27° E. The formation consists of broad belts of rather tough, rusty quartz-beds, alternating with softer sandstones, harder quartzitic layers and a small variety of other rocks. In character the series is a fair mean between the altered quartz of the north slope of West Mountain and the unaltered quartz series of Saline county. The appearance of the rusty quartz rock at the surface near the mouth of the shaft probably comes from the partial alteration of the bed in place by the action of thermal waters. A few rods down the steep gulley leading from this point, are several blocks of quartz, each of several hundred pounds weight, which have been carried down from an unknown position upon the mountain side. These are coated upon one side with tetrahedrite and similar silver-bearing minerals; but when an attempt was made to remove a piece, the film was found to be extremely thin and almost impossible to collect. Perhaps diligent prospecting would reveal the natural outcrop and show a deposit of some real value, but there are no indications of it at present in the Shippey mine. Below this transported material a pit has been dug at one side of the stream's channel, through which some thin bands of schistose rock seem to follow the strike of the formation. These are much contorted and lie in a streak which closely simulates a vein.

The principal workings consist of a shaft, 8 by 12 feet, pitching about 80° for the first 20 feet, then at an angle of 60° or less, for 70 feet, not directly in a line with either dip or strike. At the bottom of this a drift has been run diagonally across the shaft, indirectly crosscutting the formations for 100 feet northeasterly and 20 feet in the opposite direction. This has developed the deposits considerably less than would have been done by a careful study of the formation, and such a method would probably have spared the largest part of the excavation, which has really uncovered very little that is not given in the natural surface exposures. As in many other cases in Arkansas, soft, colored deposits have been regarded as the valuable mineral. If anything which will pay the cost of mining is ever raised from this mine, it will be in the nature of gold quartz or a silver-bearing mineral from crevices where it has sublimed. The decomposed sand-rock and clay "gouge" will not carry it. The results of assays which fairly represent the product are given in Table I., Nos. 24, 25 and 26. A report was made upon this mine by an assayer of local repute, who claimed to have found an average value of $80 per ton from a careful sampling of two well defined veins in the drift, aggregating eight feet in width. This is about the width of a breast at one part of the mine, where the red "gouge" is abundant, but the structure is not that of a vein, nor do the

Survey's assays quoted confirm the report. Interested parties exhibited a specimen of very white quartz with gold nuggets, totally unlike anything which occurs in that vicinity. Having investigated these matters with especial care, I am satified that the whole southern slope of West Mountain, wherever the quartz is exposed, is equal in value to the deposits here worked. But none of these deposits have yielded valuable returns by repeated assays and tests of the most delicate nature.

CHAPTER VII.

Garland County Concluded.—Northwestern Portion and the Southeast Corner of Yell County.

The Sugar Loaf and Mazarn Anticlines.—Going northwest from Hot Springs, by way of the Cedar Glades road, in section 20, 2 S., 19 W., the Sugar Loaf Mountain is crossed where it rises like an impregnable wall from the southern side of Horse Shoe cove. The rocks exposed in the crest of the ridge are similar to those in an equivalent position on West Mountain. As before stated, the fold, which is here irregularly eroded, being near the fault, trends S. 63° W., across Garland county. Its prolongation westward is not conspicuous, as a rule, its topography, for the most part, being such as to conceal the structure when viewed from the roads. Bull creek has cut its way through the anticline on section 35, 2 S., 20 W., and the main road from Hot Springs to Bear City crosses the axis approximately in the southeast quarter of section 34. Mazarn creek for the greater part of its lower course is very near this axis.

Horse Shoe cove is a remarkable amphitheatre, due, in part, to structure, and perhaps even more to erosion; but structure and erosion together are insufficient causes, I think, to have produced the effects as we find them. The supposed fault, passing just outside the eastern wall of the cove, will, however, furnish the required explanation. Descending the northern and western slopes of Sugar Loaf Mountain, the road passes across a syncline to the reverse dip, which, at the stone-walled spring in the southwest quarter of section 19, 2 S., 19 W., is nearly vertical, S. 27° E. The rock here exposed is thick bedded gray shale. About one mile beyond this on the Cedar Glades road in section 24, 2 S., 20 W., the dip is N. 27° W., in black shales soon overlain north of this, on another road, by yellow, sandy shales with the same dip.

Bearing northwest across sections 24 and 23, 2 S., 20 W., another axis is crossed in section 23, at the headwaters of Bull creek, in a ravine where extremely hard, dense quartzites, or altered quartz rock, are exposed in a good section in which the rocks are vertical. The fold which this represents seems to cross the Ouachita river about the southeast quarter of section 31, and to appear upon the main Bear City road from the east, not far from the southwest corner of section 28, 2 S., 20 W., passing out of Garland county into section 31, 3 S., 22 W. The prolongation of this fold in Montgomery county strikes near the eastern base of the ridge locally known as the Mazarn Mountain. Continuing through section 23, the tough quartzitic rocks dipping 70° or more, S. 27° E., shade off below into sandrock, which is underlain by hematite shale. Intercalated strata of black shale may be included in this section, but there is no very direct evidence of this, except at other points not far away, but with a different erosion. Exposures upon the headwaters of Clear creek, plainly show the black shales in somewhat the same relations to the hematite shale and the quartzose beds as they occupy in Pulaski county. There is little doubt that such alterations occur here also, but in many places the shales are obscured by detritus upon the hillsides. A section in a ravine leading up to the Mozambique tunnel shows the reddish shales in juxtaposition with underlying siliceous beds quite like those which are exposed on Rock creek in Pulaski county. Upon other grounds, also, they seem to be near the base of the series, as those undoubtedly are.

The Mozambique Tunnel.—The Arkansas Mining and Smelting Co., has run a short tunnel (eighty feet at the date of examination, Aug. 4, 1887) into a hill of the red shales, which here dip 32°, N., 27° W. The tunnel has been cut diagonal to the dip, so as to crosscut the formation somewhat obliquely instead of following the strike of any layer. The location is on the northeast quarter of section 22, 2 S., 20 W., near the line of section 23. The position chosen for working is well up the hill, and not at the lowest horizon of the shale series. The course of the tunnel is more nearly parallel than perpendicular to the face of the ridge, and the depth gained as the excavation proceeds is but slight. At the entrance there is a thick formation of reddened clay, much like a hard fire clay, but not pure. Interstratified with this are thin seams of iron hydroxide (limonite), which also interlace through many of the joint crevices, making a coarse net-work throughout, but becoming more confined to stratification planes in thicker bands inside the tunnel.

At its base the indurated clay is dry, but it gradually becomes wet and plastic, and in some places is quite soft. Occasional seams of quartz, occupying bed planes, occur in this formation also; they vary in thickness from half an inch to six inches and more. There is also a little of the altered quartz, or quartzite, similarly disposed. The main formation extends nearly the full length of the workings, being overlain by a deposit of hematite shale ten feet in thickness, which is high above the tunnel floor at the entrance, dipping at such an angle as to be cut near the inner end. About 120 feet west of the dump a cut was made upon a ledge of lean iron ore and quartz, dipping in about the direction of the main formation, but much more steeply—nearly 80°. The iron bearing, or limonite portion, overlies the quartz, which is in two layers, one being closely attached to the iron deposit and the other lying in the midst of the soft shales below. The whole has the appearance of an old hot spring product, resembling in many respects some of the Trap Mountain relics already described. The reddish and whitish shales weather upon exposed lamination planes in a peculiar manner. These surfaces are frequently dotted with little rectangular spots of darker hue, red and brown, apparently produced by the local decomposition of crystals of pyrites, a mineral which occurs in a similar position in the deeper layers.

The Mozambique had not been developed enough when visited to make its value determinable. The assays reported in Table 1, are fair averages of the product in August, 1887. The ground is easily worked, but timbering will eventually be required. At present there are no signs of ore except the quartz and the iron bearing deposits.

At a spring in Mozambique valley, about three-fourths of a mile below the tunnel, some of the black shales are tough and laminated, resembling thick slate, but not sufficiently thin or durable for roofing purposes.

Continuing in a northwest course through sections 22 and 16, across Clear creek to the Glazypool valley, the road is for the most part over the black shales, with steep dips S. 27° E., becoming evident in section 16.

The Clear Creek Syncline.—It is probable that a syncline is represented by the valley of Clear creek, which closely follows the strike of the beds. Holman's creek also follows it in part of its course, as does the lower valley of the South Fork of the Caddo river, in Montgomery county.

The Golden Wonder and Gray Eagle Axes.—At the bend of the road in section 9, 2 S., 20 W., near McGrew's house on the Glazypool, we have risen in the series again to the sandrocks, which are here nearly vertical, forming ridges upon the southeastern side of the valley. Soon after crossing Glazypool creek at Dr. Shippey's, on the north half of section 9, the dip of N. 27° W., appears again. It would thus seem that the creek is following still another anticline. Prolonging the axis of this fold, we shall find it crossing the Ouachita river near the middle of section 18, 2 S., 20 W., passing out of Garland county in the southwest quarter of section 22, 2 S., 21 W. It will be referred to elsewhere under the head of the "Golden Wonder belt."

This axis after crossing four or five sections in Montgomery county, passes south of Bear City, reenters Garland county and continues through its western border in a direct line, again leaving the county near the northwest corner of section 19, 3 S., 22 W. The Golden Seal mining claim and a few others are in Garland county not far from the line, but will be described with others which occur just over the boundary in Montgomery county.

A parallel fold farther north we may call the "Gray Eagle belt," on account of the occurrence in its course of mining locations under this title. The axis is not very evident along the route followed in Garland county, but in other places vertical strata have been observed between reverse (anticlinal) dips at points in the supposed courses of both this and the Golden Wonder axis. These facts are more conspicuous in Montgomery county not far west of the Garland county boundary in range 21 W., and still more so in range 23.

The folds which have been described as traversing the region southward, can all be traced without difficulty along their courses west of Garland county, but there are some more northern axes in Montgomery and other counties, which, though parallel to these, were not so plainly observed in the region now under consideration. The explanation of this was not positively discovered, but there are some indications that the extra uplifts run out before reaching the Ouachita river; and from more than one standpoint the facts lend support to the theory of the occurrence of faults not yet traced. It is possible, however, that the route followed and the lack of time to study the country thoroughly prevented observations sufficiently detailed to detect changes of dip which may really occur. The Gray Eagle axis seems to pass near the divide between Glazypool and Mill creeks, and the changed course of the Ouachita river at the mouth of the latter stream, may be due to the influence of the fold, which is a very marked feature in the landscape for many miles through Montgomery county.

The Accident Axis.—An axis which is prominent and persistent far to the southwest, if prolonged to this region, would strike near the southern base of Mill Creek Mountain. The fold which this represents will be described in the proper places in this report under the name of the "Accident anticline," a term borrowed from the mining parlance of the region.

The Broken Rock Dislocation.—There are some indications of a fault following the general course of Little Blakeley case there is reason to look for its continuance in depth off to the southwest. The value of the ore depends upon circumstances which are not to be made out without thorough study. The ore is not such as would attract the attention of a metallurgist, nor is it regarded as high-grade by the owners. A sample of the quartz from the south side of the shaft at the bottom, yields traces of gold and enough silver to make a visible bead.

The Lamb Lode.—On the northwest quarter of the northeast quarter of section 18, 1 S., 20 W., two locations have been made. The dip of the strata at this point is 30° N., 27° W. The outcropping rocks are manganese ore and soft, red, sandy iron ore, overlain by red sandstone, these being overlain by yellow sandy shales, above which are the black shales which form the valley of Spring creek. This section is apparently identical with that upon the south slope of Blakely Mountain, as far as it goes. A qualitative analysis of the ores made by the Chemist of the Survey gives the following results:

	Black Ore.	*Red and Black Ore.*
Manganese	Chiefly	Chiefly.
Iron	Considerable	Very considerable.
Cobalt	Small quantity	Slight, but more than black sample.
Barium	Considerable	Considerable.
Sodium and potassium	Little	Considerable.
Magnesium		Slight, very.
Aluminium	Very little	Considerable.

A similar outcrop of red sandstones, presumably of the same horizon, occurs west of the Golden Crown mine upon the southern face of the ridge upon which it is situated.

The "Spanish Diggings."—A few hundred yards west of the Golden Crown shaft, upon the north side of the ridge, there is a deep bowl-shaped depression, 100 feet in diameter, containing considerable soil, upon which large trees are now growing. This is regarded by the inhabitants as one of the so-called "Spanish diggings," where it has been supposed the early Spaniards made excavations for the purposes of gold mining. This pit is said to be one of a series occurring at nearly the same elevation along the north side of this ridge, all, I believe, west of this point. The bowl, has a slight indication of a break in its outer wall, and there is unmistakable evidence that a stream much larger than the surface drainage could have required, has started from the depression itself. There is no dump and no relic of one. The shape and position and all the surroundings are precisely what would be produced by a flowing hot spring in such a formation as the one which outcrops here, and there is nothing whatever about the place which would be attributed to human agency by one accustomed to studying archaic relics. The rock is what is known as novaculite.

Blakely creek and the streams north of the Ouachita river have carved canyons in the hard grits which become prominent towards the boundary of Yell and Perry counties. The black shale which constitutes the floor of the valley at the mouth of Brushy fork is a horizon which marks the line between the great series of tripartite shales heretofore examined, and the series of grits which come in on the north.

THE AREA OF THE LOWER GRITS.

A good section of the lowest members of what we may provisionally call the millstone grit series is afforded in the canyon of Blakely creek, especially in sections 22 and 15, 1 S., 21 W., where they are heavily bedded, and dip 45° N., 27° W. The black shales appear again above these in sections 10 and 11, but the topography has changed, and the grits are in the ascendency, each successive shale formation being thinner and separated from the preceding one by a thicker stratum of grits.

The Linyear Lode.—A few rods southwest of Gray Fisher's house a quartz bed two feet thick crosses a hill on the right bank of the Brushy fork of Blakely creek, in section 10, 1 S., 21 W. This rock is overlain by light colored shales penetrated by numerous very thin quartz seams. The main quartz mass has fine crystals of large size, rather opaque, and often dark gray or black. In this portion there are occasional small crystals of galena and chalcopyrite (copper pyrites).

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occupy the territory so completely that it was only necessary to go within two miles of Onyx P. O., to H. W. Brannam's house, on a fork of Graham creek, *to be satisfied that farther travel in this direction would be fruitless. It happens that the line of fault frequently referred to in these pages, bears in a course which would take it very near this turning point in the journey. The evidence, such as it is, does appear to confirm the hypothesis of a continuance of the fault across this area, but the question deserves further investigation. The structure changes southwest of Onyx in a confusing manner, and there is little doubt that other faults come in to complicate matters.

The Crystal Hill and Graham Creek Disturbances.—On section 1, 1 N., 23 W., there is an exposure of the tough, gray laminated grits, upon two dips, standing up against each other like the slopes of a roof. From observations southwestward, it would seem that this is the course of the Crystal Hill anticline. Another similar break in the strata with similar change of dip occurs in the slates southward in Montgomery county and several instances of the kind were noted in Scott and Polk counties. None of these have caused extensive "throws" upon either side of the faults. They are probably "slips," which have been of more than local origin, but which have resulted in small but variable dislocations in different situations. It is unsafe to generalize upon such phenomena without wider knowledge. From the fact that hot spring relics are extremely rare along these fault lines, it is inferred that the latter are comparatively recent and that the disturbances have been chiefly of the nature of the settling of the strata rather than of elevation stresses.

Evidences of a fold are apparent in section 26, 2 N., 23 W. As this was again observed in section 24, and in sections 19, 17 and 9, 2 N., 23 W., on the road from Thomas Keener's to Nicholson's, in section 9, on the road from Danville to Hot Springs by the way of Buffalo gap, the name Graham creek axis is appropriate. The southwestward continuation of this anticline was also crossed near the southern line of Yell county in 1 N., 24 W., beyond the southern base of Muddy Mountain, and not far from Thomas Semon's residence.

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*This stream, a prominent branch of the Fourche la Fave, is recorded upon some maps as Grave creek. Brannam's is on sections 8 and 17, 2 N., 22 W.

At the chalybeate spring in section 2, 2 N., 23 W., the overlying rock is a sandstone, to which an iron cement is attached below where the water emerges. Occasional quartz crystals occur in seams in the sandstone. At Thomas Keener's on section 23, soft red sandstone composes the valley, and is overlain by hard, gray grits. The horizon of these beds is much above the base of the millstone grit.

The Irons's Creek and Muddy Mountain Axes.—There is apparently a narrow fold which bears southwestward through section 7, 2 N., 22 W., and, as near as may be, through sections 13, 14, 22, 21, 29 and 30, 2 N., 23 W., and passing across Irons's Creek Mountain, leaves the county in section 7, 1 N., 24 W. This will be referred to hereafter as the Irons's creek anticline.

Between Brannam's and the Dardanelle road on section 11, 2 N., 23 W., there is a broad, sandy, alluvial tract, and the sands constitute the surface terrane for some distance down the road towards Mt. Ida. Occasionally the soil is richer on the bottom lands, as at R. M. Stacey's, on section 15. A well at Aly Post-office, southeast quarter of section 20, was excavated through eight feet of the sandy soil, underlain by soft sandy shale. The valleys run in this shale, with steep canyon-like walls of the overlying bluish gray grits.* The sands continue to about section 31. Excellent pine, oak, and hickory timber occurs in this region.

Muddy Mountain is crossed near the southern edge of the county in 2 N., 24 W. This ridge presents a good exposure of the grits in a monocline dipping 30° to 35° N., 20° W., but a fold occurs near the base of the south slope where erosion has exposed the shales, which appear in several successive valleys, the ridges all being crowned with massive grits. The red and yellow soft sandstones appear half-way up the eastern face of Muddy Mountain in the gap through which Irons's creek flows. The anticline was not very satisfactorily studied, but enough was seen to warrant the mapping of what will afterward be referred to as the Muddy Mountain axis. This axis passes very near Aly Post-office. Northwest of Muddy Mountain Irons's creek flows in a peculiar course, which is presumably due to a fault or a syncline. The general aspect of the topography is like that of a synclinal trough, and this idea gains support from the fact that it is the direct course of the Lost Mountain syncline in Polk county.

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*Colton's map of Arkansas, which is fairly accurate for general purposes, is misleading in this portion of Yell county. The muddy fork of the Ouachita river is wrongly located.

CHAPTER VIII.

Hot Spring County.

The metamorphic rocks which make their appearance with a steep southward dip at the corner of Garland county, on section 15, 3 S., 18 W., continue eastward in considerable variety. Slates and quartzites with some siliceous dolomite, obscured at intervals by post-tertiary clays or lean iron ores, make up a section which cannot be readily worked out in a day or two.

The Magnet Cove.—On the divide between Tiger* and Cove creeks, through the northeast quarter of section 24, especially on a hill leading down into a cove, just east of Holt's house, there is a soft sandy terrane, closely resembling the red and yellow beds which are conspicuous landmarks in Yell and Garland counties, and in other places northwest of this region. But there is a lack of uniformity in these widely separated sections in other respects. The Magnet Cove outcrops are not associated with grits like the others; they are irregular, and in some portions contain small rounded fragments and large masses of idocrase studded with brookite. It is almost impossible to make out the structure, and in all the sections observed the rocks are associated with anhydrous siliceous sinter and aluminous deposits.

The Cove is the relic of an ancient basin of thermal springs. The proof of this is apparent in the mounds within the basin and in the special character of the deposits of which these mounds are composed One of these mounds, made up of ferrous dolomite (brown spar) partly altered to ankerite near the surface, and connected with the outcrop of siliceous dolomite previously mentioned, occurs upon the Snow farm in section 19, 3 S., 17 W. At the southern base of this exposure valleys, the ridges all being crowned with massive grits. The red and yellow soft sandstones appear half-way up the eastern face of Muddy Mountain in the gap through which Irons's creek flows. The anticline was not very satisfactorily studied, but enough was seen to warrant the mapping of what will afterward be referred to as the Muddy Mountain axis. This axis passes very near Aly Post-office. Northwest of Muddy Mountain Irons's creek flows in a peculiar course, which is presumably due to a fault or a syncline. The general aspect of the topography is like that of a synclinal trough, and this idea gains support from the fact that it is the direct course of the Lost Mountain syncline in Polk county.

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*The local pronunciation is "Tee-gur."

phy from that just described, there is a flat patch of ground strewn with gray sandstone boulders and having some soil, underlain with an uncertain aggregation of rare minerals. Large quantities of material have been shipped from this locality. The same formation is again exposed at the forks of the cross-road on section 16. Rutile and brookite are very abundant in remarkably fine specimens along the streams in sections 17 and 18, especially near a spring at Holman's farm on section 18. In going across sections 21, 16 and 17, one retraces a series similar to that which is exposed southward. At Retherington's in the northwest quarter of section 17, brookite, etc., is scattered about the surface of the ground, and a considerable deposit of pyrite, in dark, tough rock, crops out across Cove creek. The pyrite was utilized by the Confederates during the civil war for the manufacture of sulphur.

Following up Cove creek, in the northeast quarter of section 17 other rocks are exposed, dipping 34° N., 27° W. There are two stages of these, one being granitic in appearance, made up of intermingled magnetite and epidote in small crystals, the other a darker hornblendic rock with magnetite and oligoclase. There is a small dike cutting across the dip and small veins of similar material following the strike. North of this the stream has cut through a heavy mass of granite, which forms high cliffs upon the west. In the upper part of the valley the bed of the stream is filled with boulders and coarse gravel composed of flinty fragments of various colors, the debris from the long, high ridges of altered quartz similar to that heretofore described from other localities.

"*The Spanish Diggings.*"—On the outcrop side of the ridge north of the Cove there are many deep pits or basins of various sizes, all of which have a comparatively narrow wall of pealite, the structure of which shows that it was accumulated by slow accretion. In every case there is a gulch leading off from the bowl in such a way as to make it clear that each spring acted as a feeder to a stream of its own. Any one who has given attention to the subject in such a region as the

Yellowstone Park, will at once recognize here the infallible signs of the same kind of activity. There is a deep seated local prejudice, however, in favor of the reference of these pits to the category of ancient mines, or "Spanish diggings," but there is no evidence sustaining this theory. No miner of any age or people ever sank pits upon the very brink of a precipice without breaking away the outer wall, if it were only two or three feet or less in thickness. Some think that the nearly level rims are the dumps, but no one would take pains to raise dumps above the original level; in other words, to build up a shaft, when the waste could easily be thrown down 150 feet over the edge of the cliff. Moreover, these bowls are invariably associated with the porcelain sinters, and the only thing about any of them approaching the dump structure is the mass of debris which has fallen into the pit itself. While there are numerous evidences that hot water poured over the edges and deposited siliceous layers by evaporation, thus building up a rim exactly as hot springs are elsewhere doing to-day.

Another theory offered in explanation of these pits is that the early savages of this country were in the habit of quarrying their flints upon these hills. Of this there can be no doubt, but the material deposited by the springs was too brittle for the uses of the Indians, while the rock they required, and which they did use, occurs in the greatest profusion over the hills, and no such excavations would be needed to obtain it in unlimited quantities. Moreover none of the implements yet discovered throughout the region of the so-called "Spanish diggings" would have been serviceable for digging and shifting material.

The Trap Mountains.—In going from Hot Springs to Malvern on the Hot Springs railway some good sections are exposed south of Cove creek. We thus pass up in the series, getting the black shales in the wider valleys and finally reaching the grits, although the topography is much affected by erosion and by the deposition of some of the more recent formations. The eastern portion of the Trap Mountains has already been described in part, but there is a most interesting region in Hot Spring county in ranges 20 and 21, which merits our attention by reason of the mining claims which have been located there.

Starting north at the fork of the creek on the southeast quarter of the northeast quarter of section 17, 4 S., 19 W., with the rocks dipping 86° N., 27° W., there is the following section:

1. Coarse, black, pyritous rock; grayish in part, very rich in pyrite.

2. Hot spring deposit (?) of soft, sandy sinter, irregularly streaked with fine alternating layers of dark brown and yellow limonite.

3. Iron ore, very fine hematite, siliceous.

4. Tough gray and black intercalated hot spring quartzites, with small percentage of iron, 300 feet.

5. Thin stage of black shales.

6. Quartzite, porcelain type, forming bold cliffs, 450 feet. Then a broad synclinal trough followed by a similar section in reverse order; dip 88° S., 27° E.

The Openings of the Garland County Mining Company.—On the northwest quarter of the northeast quarter of section 17, 4 S., 20 W., the Garland County Mining company has done a little work in the shape of a tunnel, crosscutting the rocks. The excavation was begun near the bed of a little stream flowing from the second ridge of South Mountain and joining Rush fork a short distance below this point. There is no vein structure visible, though some of the layers, or thin beds, are siliceous and others ferruginous, with some signs of alteration in place, and possibly of mineralization. The dip of the whole series is 77° S., 27° E., and quite regular. The cut and tunnel bear nearly south, rising in the series as they go into the hill. The section, beginning at the breast of the tunnel (July 23d, 1887) and going outward, or down the series, is as follows:

1. Glistening, corrugated graphitic shale, compactly pressed, and somewhat resembling coal seams in which *Lepidodendron* remains have been preserved. This is regarded by

Yellowstone Park, will at once recognize here the infallible signs of the same kind of activity. There is a deep seated local prejudice, however, in favor of the reference of these pits to the category of ancient mines, or "Spanish diggings," but there is no evidence sustaining this theory. No miner of any age or people ever sank pits upon the very brink of a precipice without breaking away the outer wall, if it were only two or three feet or less in thickness. Some think that the nearly level rims are the dumps, but no one would take pains to raise dumps above the original level; in other words, to build up a shaft, when the waste could easily be thrown down 150 feet over the edge of the cliff. Moreover, these bowls are invariably associated with the porcelain sinters, and the only thing about any of them approaching the dump structure is the mass of debris which has fallen into the pit itself. While there are numerous evidences that hot water poured over the edges and deposited siliceous layers by evaporation, thus building up a rim exactly as hot springs are elsewhere doing to-day.

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1. Glistening, corrugated graphitic shale, compactly pressed, and somewhat resembling coal seams in which *Lepidodendron* remains have been preserved. This is regarded by

the miners as rich ore, but it yields only traces of gold and silver as may be seen in Table 1. Many regard it as lead ore. There is no trace of lead in it, but it may possess some economic value as a graphite deposit. The extent of the beds is not fully proven.

2. Impure graphitic shale with streaks of brittle white quartz, fifteen feet. This yields no trace of gold or silver either in the shaly portion or in the quartz, tested separately.

3. Slightly graphitic, siliceous shale, pyritous in places.

4. Tough, quartzitic rock in seams, with quartz occurring at intervals, within forty-five feet of the entrance of the tunnel.

5. Quartz with streaks of ferruginous matter, or limonite, six feet.

6. Thin streak of the so-called ore, twenty-two feet from the entrance.

7. Quartz band.

8. Black shale, with graphitic scales, but more earthy and with much less graphite than No. 1, five feet.

9. Black shale, with little or no graphite at the top, becoming gradually like ordinary shale, dark colored, twenty-five feet, partly in the open cut.

There is nothing in this property which suggests the presence of any workable deposit unless it be iron ore and graphite. The former, even if suitable for smelting, is not abundant enough to be profitably utilized; but the latter mineral may possibly be eventually worked to advantage. It comes from the mine in large masses which are comparatively free from foreign matter, having a brilliant lustre, a foliated structure and a texture quite homogeneous and free from gritty mixtures.* This is not a vein, but a regular interstratified metamorphic terrane probably of carboniferous age, though its exact relations in the geologic scale have not been clearly ascertained.

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*Graphite deflagrates and burns vigorously when heated with saltpetre, (nitre). Lead ores yield the metal readily when properly heated with fluxes and reducing agents in a crucible. Both these tests have been repeatedly applied to the products of this mine, with the results given in the text.

Carbonate Hill; the Buena Vista Lode.—Three-fourths of a mile south of the Alpha, in the southwest quarter of section 30, after crossing the Fifth Mountain, at the forks of Big Hill creek, the Sixth Mountain bears away to the west. At this point it has been named "Carbonate hill," though no carbonate exists in its neighborhood. A claim has been located in the end of the mountain under the title of the Buena Vista lode. A small amount of work had been done upon it, July 23, 1887, exposing a large body of hard quartz, which carries a considerable amount of pyrolusite or manganese dioxide. The occurrence has much of the typical vein structure and should be thoroughly prospected, though there seems little hope of obtaining workable quantities of gold or silver. The manganese ore, however, may be profitable to work, as it is very well situated in every respect, but from the indications at the date of examination, no certain statement can be made.

Big Hill creek belongs to the Caddo drainage. This stream flows south through the west edge of section 31, 4 S., 20 W., passing over graphite shale and ordinary black shales and tough, dark, blue dolomite, the whole series dipping S. 27° E. at a high angle. The graphite here is excellent and readily accessible. None approaching it in purity was observed elsewhere in this region. It would seem that a remunerative industry might be built up near Carbonate hill, by the mining of graphite and manganese, if these are found to be abundant. At Mrs. Duffee's in the southwest quarter of section 31, 4 S., 21 W., a road leads due west, passing through sections 36, 35 34 and the corner of section 33, 4 S., 21 W., into section 28, etc. A very good section, the counterpart of those previously made out, may be studied from Thompson's mill up to the divide between the Caddo and the Mazarn creeks, but the structure is mostly obscured both south and north of this area by the excessive erosion and subsequent deposition of detritus. Very thick accumulations of loose white sand make up the surface terrane in section 36 and westward, and this, with red and yellow sands and shale debris, covers most of the area north of the mountains.

The Una Lode.—One half a mile east of the mountain road, in section 15, 4 S., 21 W., are the Lightfoot Springs, which have long been held in esteem on account of the supposed medicinal properties of their waters.

The proprietors of the hotel at this place have located a claim known as the Una lode upon one of those nearly vertical outcrops, which in Arkansas usually consist of stratified beds simulating veins. The type here shown is much like that of the Buena Vista lode at Carbonate hill, but in the Una, the evidence of hot spring action is much more pronounced.

There is much pyrolusite and limonite in the deposit. In some streaks the two are so mingled as to make the ore unsuitable for market, but hand assorting would probably enable a large portion of it to be utilized, in case further development proves the deposit to be sufficiently extensive.

At Bowman's, just beyond the range line, section 13, 4 S., 22 W., the principal terrane is intermingled with quartzites. Near the Garland county line the laminated sandstones, or grits, give character to the topography and this is especially the case in sections 17 and 18, 4 S., 22 W.

CHAPTER IX.

Montgomery County.—Northern Portion, Including the Mining Districts.

We shall begin with the northeastern portion of the district, continuing the subject where it was left in the previous review of a part of Yell county at the close of chapter VII. South of the county line on the Mt. Ida and Dardanelle road, the dip is N. 27° W., 25° to 30°, and continues for several miles, the same in direction as in the southern part of Yell county, but gradually increasing in its inclination. At Reed's mill, and some distance below it, the bluffs are table topped and chiefly composed of the shales, dipping more than 40°. The Muddy fork has cut very deeply through these strata and its character, as implied in its name, is due to the soft nature of the beds, although some of the layers are sufficiently tough to have retarded erosion in a marked degree. The bluff country continues down the creek in ranges 23 and 24 nearly to the base line.

The Crystal Hill and Big Fork Anticlines.—Along the main road, the dip increases gradually to vertical and changes to S. 27° E., between two eastward flowing branches of Muddy fork, north of the base line in 1 N., 24 W., probably in section 24. This axis is not a prominent landmark, but as it was crossed again in Polk county, and as it probably has been influential in producing a prominent ridge in northwestern Montgomery county, it may appropriately be called the Crystal hill anticline. The southern branch of Muddy fork seems to run in a syncline about on the base line, the dip of 60°, N. 27° W., occurring to the south, followed by a thick series of nearly vertical shales. The road cuts these shales diagonally, which makes the section appear thicker than it really is; but judging from the developments eastward in Garland county, it is not improbable that, upon closer scrutiny, one or more faults will be discovered here. About on section 12, 1 S., 24 W., the dip changes again to S. 27° E., and continues thus for some distance, followed again by vertical shales, changing to 50° N., 27° W., in section 13. This fold occurs in Polk county and will be spoken of as the Big fork anticline. A hasty examination of such a folded section is often misleading, but from the presence of many intercalated beds of quartz in the broad shale exposures, it would seem that this point is low in the series, in fact at the horizon of the beds observed in Saline and Pulaski counties. It is certain that these quartz strata occur at points farthest removed from the grit exposures north and south of them. Wherever there is a cross valley, the shales are exposed, the grits appearing only in the ridges, and not in all of these. There is some exceedingly interesting geology to be worked out in the few townships comprising the adjoining corners of Yell, Garland and Montgomery counties. The time which could be devoted to this area was too short to permit of a complete examination.*

A peculiar nodule was found at Metaline Springs, in section 11, 1 S., 24 W., weighing some twenty pounds. It was not found in place, but similar masses are said to occur in a regular layer in the shales which underlie the grits.† The Chemist of the Survey reports the results of a qualitative chemical analysis of the incrustation of this nodule as follows:

"No. 1032—Qualitative analysis:

$\left.\begin{array}{l}\text{Iron,}\\\text{Aluminium,}\end{array}\right\}$ chiefly;
Silica, much;
Calcium, very small quantity;
Sulphuric acid, very small quantity."

Quartz layers appear above the nodulary bed in section 24. Tests of this quartz for gold and silver show no trace of either metal. Underlying the nodules are laminated sandstones, which form the lowest bluffs near and on the north side of the Ouachita river. Crossing this river where it flows northward, in the northwest quarter of section 30, 1 S., 23 W., the Cedar Glades road keeps south of the stream until it reaches the southeast quarter of section 24. The course of the Ouachita is very tortuous in this region, and it is bounded by precipitous bluffs of millstone grit upon the north, while these strata are almost wholly wanting upon the south. It runs for the most part in a monoclinal valley, in which the dips are all N , 27° W., varying from 45° northward down to about 25° near the south fork, in 2 S., 23 W. There are evidences of a fault at this point, and the dip is reduced to 15° or 20° for a short distance, with little or no change of its course. Across the intervening country in 1 S., 23 W., are many beds of quartz in the black shale. Samples of the quartz taken from different beds were tested by the wet method by the Chemist of the Survey for gold and silver, but they yield no trace of either. The amount of alluvium deposited by the Ouachita in former times has been enormous, enough to largely obscure the underlying structure for miles along this part of its course.

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*See remarks upon this subject in the latter part of the review of Garland county, and in the discussion of Yell and Polk counties in chapters VII and XIII.

†In Polk county, three miles north of Dallas is a locality abounding in such nodules.

THE MINING REGION.

The area in Montgomery county that has furnished the impetus to the mining operations of the last few years includes considerably less than one hundred square miles, its extreme limits being the west line of Garland county upon the east, the west line of range 23 upon the west, the boundary between the second and third tiers of townships south of the base line upon the south, and the north line of the second tier of townships upon the north. Starting from the eastern side of this district where it was left in reviewing Garland county, one may trace the direct prolongation of the folds there marked out, and there is no decided break in the continuity of these folds as one goes westward. It happens that each mining district occupies a separate cadastral or United States land survey township. This, however, is a coincidence. For the pur from the developments eastward in Garland county, it is not improbable that, upon closer scrutiny, one or more faults will be discovered here. About on section 12, 1 S., 24 W., the dip changes again to S. 27° E., and continues thus for some distance, followed again by vertical shales, changing to 50° N., 27° W., in section 13. This fold occurs in Polk county and will be spoken of as the Big fork anticline. A hasty examination of such a folded section is often misleading, but from the presence of many intercalated beds of quartz in the broad shale exposures, it would seem that this point is low in the series, in fact at the horizon of the beds observed in Saline and Pulaski counties. It is certain that these quartz strata occur at points farthest removed from the grit exposures north and south of them. Wherever there is a cross valley, the shales are exposed, the grits appearing only in the ridges, and not in all of these. There is some exceedingly interesting geology to be worked out in the few townships comprising the adjoining corners of Yell, Garland and Montgomery counties. The time which could be devoted to this area was too short to permit of a complete examination.*

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*The Golden Wonder Belt.**—It will be remembered that in Garland county, where it adjoins Montgomery county, in section 23, township 2 S., 21 W., one of a series of parallel axes of elevation is exposed, trending in the general course of Glazypool creek, where erosion has laid bare the black shales. West of the Ouachita river this fold has resisted denudation, or has been subjected to less wear, so that the path of the axis is marked by highlands of the tough quartzose and sandy layers, the soft shales being uncovered where ancient or existing deep valleys cross the axis. The latter beds have not been subjected to extensive etching. Differences in the elevating force may also have had much to do with the changed conditions in Montgomery county. It is not safe to attempt close tracing of the folds over wide areas without better maps than we now possess, but the route pursued, as well as the remarkably direct courses of the axes, have made the work less uncertain. Thus, if the prolongation southwestward of the Golden Wonder anticline be plotted, using the best existing maps, the line leads almost exactly to Caddo water gap. Tne writer's notes upon that region contain the following entry: "At the forks of the road in the gap, where I crossed the Caddo and turned west, a very tough, dark colored, altered quartz rock appears. This is here said to be the Golden Wonder ore, which it certainly resembles exactly in position, in the intercalation of shales, and in the fine net work of quartz seams." It is reported also that some prospector has actually traced this stratum by its outcrop, from the Golden Wonder mine, south of Bear City, to this point. Further quoting the field notes: "Just before reaching the crossing there is a peculiar S-shaped twist in the rocks within the space of fifteen feet transversely which seems to have more than a local extent in the direction of the strike." Equivalent rocks, with the same contortions, were seen and noted in the valley of the south fork of the Caddo in section 34, 4 S., 25 W., and on Shield's creek beyond, where the anticline occurs directly in this axis prolonged. Observations of like character were made also in 5 S., 26 W., and in 7 S., 28 W.

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*By referring to this heading under Garland county, the course and character of the extensions of this area in the adjoining territory will be more clearly understood

A similar irregularity was observed in the Golden Wonder mine strippings also, but the excavation had not gone far enough to expose it well.* These are believed to be relics of ancient hot springs with siliceous waters, of the type now prevalent at the city of Hot Springs.

So far as geologic and mineralogic conditions are concerned, there can be no reason why the mining of gold ore may not be as profitable at Caddo Gap as at Bear City, if attention be confined to the Golden Wonder quartz. The only difference between the two localities is one of quantity, with, possibly, a greater degree of intensity at the latter place. The country rocks of this region are not such as usually carry gold or silver. We should expect these in the granites and associated rocks which form the nucleus of the region, or in adjacent igneous outflows which have brought up material from considerable depths in the interior of the earth. There are none of the latter class of deposits in this district, and the former are not near the surface. The only chance, therefore, to strike workable ore, bodies in Montgomery county, is in the material that has been carried up by hot springs. Relics of this kind are abundant in portions of the Golden Wonder belt, particularly south of Bear City and near Caddo Gap. If the sources of the products of these springs had been auriferous, it is probable that the tough quartz would now carry the metal. The absence of any real vein structure is not a favorable indication, to be sure, but even over the wide area covered by the beds we might hope to get a low grade ore which would be workable.

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*South of Dallas, in Polk county, identical observations were made in one of the properties named "The Copper Queen," belonging to Mr. Worthington. This, however, is far out of the range of the Golden Wonder axis.

The only locality at which the quartz of the Golden Wonder mine has been really worked, is in section 31, 2 S., 21 W., on a tributary of Bear creek. There is no mine here, but a quarry or simple cut, from which the rock is taken as it comes and is sent to mill without assorting. A considerable amount of soft shale from adjacent layers is included in the material transported, though it is not claimed that it carries any metal. The Golden Wonder mill at Bear City, more than a mile from the quarries, is the ordinary 10-stamp gold mill, with automatic feeders. Amalgamation in the usual way by inside battery plates and outside tables is the process adopted for gold saving. The manager of the company stated that the tough, dark quartz rock, already described, was the valuable ore. He also remarked that only those portions that have fine seams of white quartz transverse to the bedding are profitable to work. Great care has, therefore, been taken to assay what he called "rich ore," and the so-called lean or worthless ore separately. The results of these determinations, made with more than usual care, appear in Table 1. The results are especially interesting from the fact that claims have been made that much higher returns could be had from these and other Arkansas ores by the use of particular mixtures in the assay crucibles. It may be positively asserted that any ore which would require such treatment in the assaying, could not be worked by the ordinary milling process.*

There are several other trenches upon the Golden Wonder claim, from which the same rocks have been quarried. Probably this stratum can be found near the surface over much of the area mapped out as the course of this Golden Wonder belt in Garland and Montgomery counties, but all the evidence collected by the Survey goes to prove the barrenness of the whole tract.

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*See the full discussion of this question in the portion of the report devoted to economic results, and in Table 1.

The Gray Eagle Belt.—The continuations of both the Golden Wonder and Gray Eagle axes have been traced far to the southwest where their structure is identical with that which has already been described in Garland county, even to minute peculiarities. Beginning in section 10, 2 S., 21 W., in Garland county, the strata exposed across the breadth of the Gray Eagle or Mammoth fold as far as the southwest quarter of section 35, 2 S., 22 W.,comprise the greater part of the Bear City mining district. The Atlas and the Mammoth mines are not far from the axis of the fold, which is approximately parallel, for a long distance, with the Crystal Springs road near the former mine and with the road from Bear City to Horse Shoe cove. There seems to be a slight bend in the strike near Bear City, but no changes in the bearing of the dip was noted greater than 4° (from N. 27° W., or S. 27° E., to N. 31° W., or S. 31° E.), except where purely local distortions occur. The upper Mazarn runs in the strike of the fold in section 17, 3 S., 23 W. There is also a vertical exposure, which is in the line of this axis, on the Caddo Gap road about two miles south of the Hot Springs and Dallas road by way of Black Springs, probably about section 8, 4 S., 24 W. It is apparently the same axis which passes near Mr. Jack's house on section 28, 4 S., 25 W. These are the only intersections of the writer's route with this axis in Montgomery county.

There are more reasons for anticipating the discovery of valuable mineral deposits in the Gray Eagle belt, perhaps, than in some others of the numerous structual lines thus far reviewed, but a study of the outcrops at many points along the axis for eighty miles offers no evidence of any important deposits yielding gold or silver. In view of the fact that claims to the contrary have been made, very great care has been taken to place the matter beyond all doubt. To this end, thorough quantitative tests by various processes have been rigidly applied, and the aid of some of the most trustworthy assayers in the United States has been invoked. The detailed report of this examination may be found in Table I, in the second part of this report.

Notwithstanding the fact that such well and widely known assayers as Professor P. de Peyster Ricketts, Professor R. H. Richards, and others, have reported adversely upon the rock mined along this belt, there has been considerable work done upon some of the outcrops of tough quartz and other layers which lie upon both sides of the axis. For some reason, no serious attempts have been made to develop these strata (for such they are) upon the southern side of the axis, except at Bear City. There are other places in which good exposures might be had, but they have been neglected.

The Lost Louisiana Mine.—About one mile southwest of Bear City, and not far from the Golden Wonder mine, there is a condition of things, which has attracted much attention, and it is not strange that prospectors of limited experience or of untrained judgment, should have selected this spot as a site for mining operations. To the average observer, the old tradition of the "Spanish diggings" has here even a more reasonable application than in other similar places, and an old hot spring bowl has been endowed with all the prestige of the fabulous "Lost Louisiana" mine of the early Spaniards. Although the total length of shafts and tunnels in this mine amounts to only 460 feet, there is but one other mine in Arkansas, claimed to yield gold and silver, which has been so much developed. Fortunately, the work done here has been of such a character as to afford most convincing proof of the real origin of the surface features as they existed when the present owners began work. Had there been any doubt of the reasonableness of the conclusions elsewhere expressed concerning the other so-called "Spanish diggings" in the State, the facts observed at this point would completely confirm those views.

The Lost Louisiana shaft has been sunk from the bottom of an old hot spring bowl. The workings are not following a vein, but are crosscutting a series of strata which are somewhat contorted and filled in with soft earthly deposits of wad or bog manganese ore. The external basin of the ancient hot spring is a pit about 150 by 60 feet across and 30 feet deep.

The shaft has been built up above the bottom of the pit to a level with the rim, to which it is connected by a platform. A light steam plant is arranged with a bucket hoist, and the development has all been done in a workmanlike manner, although no reason is apparent for the direction which the excavations have taken, except in the case of a side passage running at first west from the south drift. In opening this passage, a mass of soft, earthy, ochreous material was encountered, bearing in a direction not strictly parallel with the main workings. This body very nearly underlies the small bowl which occupies one side of the main depression at the surface. The writer has no doubt that it is the filled throat of an ancient spring. The character of the filling, which is like many of the iron ores and bog manganese deposits of the region; the occurrence of pockets and patches of the same stuff all through this and the neighboring mining properties, as well as the structure at the surface and underground, all point to this conclusion. Anyone, who has studied the active and extinct hot springs of other regions, will at once recognize here all the characteristics of this class of products.

The strongest advocates of the Lost Louisiana as a mining property claim that its wealth is locked up in the very minute seams, mere tissue plates, of quartz, which penetrate the rocks within a certain distance of the old throat, or, as they claim, the abandoned shaft of the early miners. There is no evidence in favor of this last opinion, but even if the "ancient miners" story were true, the fact of the abandonment would furnish proof of the impoverishment of the mine. If the rock itself be impregnated with ore, there are thousands of places over a vast area throughout this region where the indications are quite as good as in the Lost Louisiana mine. The formation which occurs here has been traced many miles in both directions with little or no variation in character, and it has been worked in other districts and in neighboring portions of the same district without success.

Much of the soft material in this property is called "telluride." Particular pains have been taken to collect and to test many samples from this and from other localities; Dr. Brackett, the Chemist of the Survey, and Mr. Frank W. Gibb of Little Rock have examined some of these; and Prof. P. de P. Ricketts, the well known assayer of New York City tested some of the Lost Louisana ore for tellurium* None of these persons has been able to detect a trace of tellurium in it. A quantity of soft material given the writer by the president of the company, and described by him as "very rich telluride," proved, upon examination, to be manganese oxide. It contained no trace of tellurium, gold, or silver. The results of assays of other samples are given in Table 1.

This mineral, a variety of manganese ore known as "wad," occurs abundantly in the crevices, and as more or less regular layers, in the much broken quartzite composing the bulk of the strata in this locality. In connection with it, and often more or less mingled with it, is a red earth containing a large per centage of iron oxide. These products may have some value in the arts, as the basis of paints and for other purposes, but there is no trace of gold or silver in them and it is questionable whether they can be profitably mined, except in situations where the old hot spring throats can be struck in the workings. The dip of the strata, barring the contortions, is about 48° S., 27° E.

No Man's Mine.—The successive layers of the rock, exposed in the Lost Louisiana mine, can be traced across the country to Bear City, where a claim has been located, called No Man's mine, upon what is probably the northeastward extension of the Lost Louisiana beds. The workings consist of a tunnel 125 feet in length, starting into the hill just opposite the centre of the city, on Rouse creek. Ninety feet from the entrance a cross gallerv runs off 75 feet towards the south, and another gallery, starting about 100 feet from the entrance, extends northward thirty feet.

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*It is impossible for anyone to fail to detect tellurium by the ordinary test, even when present only in a very minute quantity.

The general dip of the strata is 60° S., 28° E., but there is some irregularity, due to contortions such as occur in the Lost Louisiana, and in one place there is an apparent low dip to the northward. This, however, seems to be a case of false bedding, or it may be a local feature due to deposition from a large hot spring of which there are other indications in the vicinity. The rock is much broken by jointing, and there are numerous large and small patches of quartz and of the red and black iron and manganese bog ores described under the preceding head. It is difficult to make out any structure, but much that would otherwise be doubtful may be readily explained by comparison with the deposits elsewhere in this district. The topography in the vicinity of Bear City and for some miles west is unlike what occurs in others parts of Arkansas, but there are striking similarities between this and a portion of the country near the city of Hot Springs. There are, of course, many points of disagreement, but none that can not be traced directly to variations in general geologic structure, which have primarily affected the drainage of the areas. The exact relations of all the beds is not wholly clear, although it can be made out without much difficulty whenever the detailed study of the region may be undertaken. The horizon is equivalent to that of the quartzites between the thick black shales and the millstone grit and it may represent the basal members of the latter series. The axis of the anticline, as in many other portions of the State, exposes the black shales, and it would seem more reasonable to expect ores of the precious metals in some of the quartz beds in this group. In other words, the relics of thermal springs which constitute the mines nearest to Bear City, and others about to be described, must have drawn their supply of the precious metals, whatever it may be, from some deeper seated source. The discussion of the economic geology of the locality is given in the second part of this report.

THE MINING CLAIMS EAST OF BEAR CITY.

Besides the Golden Wonder and the Lost Louisiana mines near Bear City, there is a number of claims lying towards the northeast and within a few miles, which have been locally grouped in two sets. The Gray Eagle and the Mammoth ores, as they are respectively known by the assayers of this district, lie in lines that are barely distinct, and they appear to represent beds not very far apart in horizon.

The Mammoth Lode, etc.—The claims which have been located upon the Mammoth outcrops, are all quite similar in character, exposing a thick layer of quartz, more or less cemented and bounded upon both sides by iron sinter. The so-called ore is a regularly stratified bed, following the dip, which is about 40° N., 27° W. The principal Mammoth opening is upon the main road from Bear City to Cedar Glades, and it has been worked by a shaft upon the side hill in such a manner as to crosscut the bed of quartz. Suydam's Mammoth is apparently upon the same bed, about one mile farther east, but a little north of the road in a gulch. Here a downward slope has been run approximately upon the dip, exposing rock of the same structure and texture as in the Mammoth itself. In both cases the overlying stage is soft, yellow, sandy shale, and the beds below are quartzose and schistose.

The Silver Spray Lode.—This lies south of Suydam's Mammoth, across the gulch, and is best exposed in some small strippings in a little side ravine. The rock is below the Mammoth quartz in position, but it is not materially different in horizon. The dip of the beds is in the same direction (N. 27° W.), but in the Silver Spray it is 48° and more. Farther south, near the head of the ravine, another opening on the same property has exposed different beds of quartz, which have a nearly vertical dip and the same strike as all the other rocks in the neighborhood. There are several layers of this material, aggregating ten feet in thickness. The quality is unlike the Mammoth quartz, being grayish, less brittle, and with little or no iron sinter.

The Golden Seal Lode.—A short distance northeast of the Silver Spray cuts, upon a continuation of the same beds, a large cut has been made near the summit of the ridge, and a quantity of the rock has been quarried. This is the Golden Seal lode. There is no evidence of a vein, and, as in all the workings in this region, the whole mass of the stratum is regarded as ore. There is no reason for this other than the reports of local assayers, which are not confirmed, however, by careful tests of the samples collected by the Geological Survey. The dip is N. 27°, W. 38°.

The Silver Spray and Golden Seal products are apparently identical, and both are known at Bear City as Gray Eagle ores. As remarked before, this rock differs from the Mammoth, which overlies it, but in neither have assays of the material shown any reason for suspecting the existence of gold or silver in appreciable quantity.

FROM BEAR CITY TO THE OZARK MINE.

Going north from Bear City towards the Ouachita river, one enters the region of the monoclinal ridges, passing down to the horizon of the black shales through the regular succession elsewhere noticed.

Cold Spring.—About half way from Bear City to the river, on section 17(?), 2 S., 21 W., there is a fine spring coming out under quartzite in black shales. Up to this point the dip is S. 27° E., but here the beds are vertical and soon afterward the reverse dip appears. The anticline thus indicated seems to be a continuation of the Gray Eagle belt. Bear Mountain is a monocline with a dip of N. 27° W. Upon the northern and southern sides and through a little gap in the ridge the black shales are prevalent, the higher rocks appearing as capping upon both sides of the Bear creek pass. The topography of the mountain is the result of erosion rather than of structure.

The Ozark Mine.—This property has attracted much attention. To a novice the structure presents features which are new and striking, and this fact is enough to make him give willing credence to all that can be said in favor of its resources.

This mine is in the north half of the northeast quarter of section 8, 2 S., 21 W., near the corners of sections 4, 5, 8 and 9. The sandy yellow shales, in tortuous layers, overlie a tough, irregular deposit of siliceous iron ore, that approaches limonite in character. This lies nearly along a stratification plane at the northwest, rather gradually changing to quartzose rock a few rods to the southeast, where it rises suddenly into a mound and splits up into several layers, penetrating the underlying black shales. A tunnel has been run at the base of the mound, starting at the lower part of the black shale, being partly in a thick layer of soft ochreous material. The opening follows the strike very closely, being half in the black shale for 120 feet, then running 40 feet in the red ore, which is here erroneously styled "sand carbonate." From this point, a cross-cut has been run 20 feet towards the south. Within 12 feet this passes out of the red ore and into underlying shales. Another cut to the north follows the dip, (N. 27° W.), but less steeply, being wholly in the overlying black shales, which are here penetrated by quartzose and ferruginous bands. At the bottom of this slope, 58 feet from the main tunnel, there is a sump of 20 feet that does not cut below the shales. The quartz seams dip apparently with the strata, except to the southwest and above the tunnel, where they have penetrated cross-crevices with dips as steep as 75° to 80.° Just back of the sump in the cross-slope, the course of the main tunnel had been extended 15 feet, at the time of my visit. Of course this follows the black shales, being nearly on the strike. Ochreous "gouge" occurs at the points near the quartz bands.

The material taken from this property and said to contain silver, is a somewhat friable black shale containing a small amount of graphite. Minute quantities of gold may possibly be obtained from the quartz bands, but these are not large enough or abundant enough to be worked. The "black mud" and the "blue mud" are soft, unctuous patches or layers of similar material, forming clayey streaks in the mass. Where the graphitic material is abundant enough to make a jet black, scarcely lustrous, paste when moistened and worked in the hand, the local assayers call it "black mud." Such portions as are, when wet, grayish, with a bluish stove-polish lustre, due to graphite, are known as "blue mud" The various qualities of these earths and shales which have been accepted in this region as ores of gold, silver and lead, have been thoroughly tested by the Chemist of the Survey and others, as well as by the writer, and they have invariably proven quite barren of all these metals. By the blowpipe, by wet and dry assays, and by the most delicate of special tests, no traces of gold have been detected. There is no difference in structure, texture, or mineralogic characters between these deposits and a very large portion of the black shales which are exposed over thousands of square miles of the State of Arkansas, except that bands of quartz or of calcite penetrate the beds in some localities more than in others.

The Black Chief Prospect Hole.—This is a mining claim owned by the persons who control the Ozark, from which it is separated by a low ridge. The location runs parallel to the Ozark, about 600 feet distant, near the centre of section 8, 2 S., 21 W. The workings when examined, consisted of a large pit, one side of which was formed by the vertical cutting down of the hillside, giving an exposure of the strata some 20 feet in thickness. The black shale and the sintery iron deposits, described from the Ozark, extend over to this point, and the only differences in the outcrop at the Black Chief from that at the Ozark, are due to greater regularity in the deposition. The assays made of the products give the same results as the tests of the output from the Ozark mine.

WESTWARD FROM BEAR CITY.

The approximate dip of S. 27° E., at Bear City continues along the road as far as the east end of the town of Crystal Springs, where the inclination is from 18° to 25°. The intervening topography is somewhat rugged, owing to the rise in the geologic horizon to the dolomites which overlie the quartzites.

The Atlas and Monarch Mines.—The Atlas and Monarch claims are in positions which appear to correspond with the prolongations southwestward of the Mammoth and Gray Eagle trend, but too little material was gathered to thoroughly establish their identity.

Crystal Springs.—In the black dolomite, near an anticlinal fold, a number of excellent chalybeate springs emerge along the sides of the stream. Some of them are quite small, but there are several of large dimensions. These springs are mostly clustered within a small area in the little town of Crystal Springs, which is admirably situated for a watering place. A few of the bowls of the springs are surrounded by evidences of former greater activity, and some have deposits which suggest that thermal waters once overflowed from them.

A smelting plant of moderate size has been erected northeast of the town. This plant was intended to treat the Ozark and Lost Louisiana ores and was nearly completed in July, 1887. There are no ore deposits, however, in the tributary country, sufficiently developed to enable the works to run. The only known smelting ores available are those which occur in the Silver City district. The products from the Ozark.and Lost Louisiana mines and their compeers, contain no lead in any form and their composition is such that they could not possibly be smelted by themselves. One is almost pure quartz and the other a graphite shale, both of the most refractory character, and the latter quite infusible.

The Accident Mining Company's Shaft.—The road leading westward from Crystal Springs passes at first over the northern slope of the fold, but a change occurs that gradually brings to view the black shales in the valley of a northward flowing tributary of the south fork of the Ouachita. There is probably a syncline of but little prominence, as a low fold appears beyond the shales, with exposures of rocks higher in the geologic scale. The Accident Mining Company has sunk a shaft in the valley, in a position which is, geologically, in the continuation of the strike of the beds exposed at the Ozark mine. The Accident shaft, however, seems to be in beds much higher than the Ozark shales. The shaft was about 80 feet in depth July 26, 1887. The dip of the rocks is steep, and the alluvial deposit being level at the top, the superficial clay varies in thickness from four feet to eleven feet upon opposite sides of the excavation. Below this, a layer of black shale is cut obliquely, with an apparent thickness of 18 feet. Under the name of "black mud," this rock has been carefully saved upon the dump. Harder rock underlies this, beneath which is more black shale claimed to be the "best ore." The lowest rock exposed in the shaft is not very different from the black shale. A certificate of an assay of a sample of this last named stratum, made by a local assayer, reports a "trace of gold, 85 ounces of silver, and 33 per cent. of lead." There is no lead in the rock. It has a specific gravity even below that of ordinary carbonaceous shale, while its bedding and the uniformity of its mass, without seams of foreign minerals of any kind, leaves no doubt of its barrenness. All assays of the material except those made by two or three local assayers, show negative results.

The Accident Anticline.—The first evidence of the existence of a fold parallel to the general flexures of the country, within a short distance northwest of the Gray Eagle belt, was obtained at the headwaters of the Mazarn river, when following up that stream from the southeast. This anticline was discovered afterwards upon the property of the Phœnix Mining Company, and since that its course has been traced southwestward through Montgomery county, and its extension has been noted across Howard and Sevier counties. Its northeastward continuation is hypothetical. This Accident anticline is characterized by long, low hills, which, in many instances, are deeply covered with detrital deposits, largely concealing the structure. The Accident tunnel (not the Accident Mining Company's property) crosscuts this fold.

Phœnix Mining Company.—The Accident Tunnel.—There is a widespread rock, or a series of rocks, probably belonging to the millstone grit, which has been a favorite with those engaged in mining in Montgomery county. It never occurs in veins or in localized deposits, but simply represents a number of sedimentary beds which are regularly interstratified in the system of grits, and it occupies a horizon near the base of that formation. Locally, it is known as "accident ore." The story goes that it was at first regarded as valueless, but that a piece of the rock accidentally sent to a local assayer gave very high returns in gold and silver. Since that occurrence many openings have been made upon this stratum, and there are extensive tracts in which it is well exposed. In the Accident tunnel, not far from the eastern base of the Crystal Mountain, the Phœnix Mining Company has made an attempt to cut through a high ridge which trends obliquely to the strike. At the point of attack the structure is anticlinal. The excavation (250 feet, July 26, 1887) is laid out diagonally across the fold. At the entrance the rocks dip 63° N., 27° W., the dip increasing within the tunnel to vertical, and then the strata are cut at such an oblique angle as to show a gradually decreasing apparent dip as low as 30° and less to the southward. The rocks vary in texture, more or less; but, for the most part, they are tough and hard, and are from two inches to a foot or more in thickness. Assays (see Table 1) give no encouragement for mining here. A Bartlett smelter was on the ground, ready to be erected.

The Phœnix Company has several other excavations along the road from Crystal Springs to Crystal Mountain, mostly in situations requiring no special mention. The products differ, however, but within the range of rocks described in connection with the other mining work in the neighborhood. The development is not extensive in any of the openings. It is possible that thorough search and careful prospecting in this region may yield some return, but there is little inducement to such work from the present showing. The most promising fields are those in which faults have opened passages for the escape of thermal waters; and the best instances of deposits thus formed yet remain to be described. There is no evidence of the existence in the rock of any mineral that could carry silver, and no one claims any appreciable amount of gold. This "accident ore" occurs abundantly in other localities, and none of it has yielded more than a few cents per ton of metallic ingredients by the Survey's assays.

Crystal Mountain.—A very interesting instance of the topographic results of geologic structure and of erosion, is afforded by the Crystal Mountain, over which the road passes between the Phœnix mining camp and Silver City. Crystal Mountain itself is very much like the typical Arkansas ridge, trending between the courses of dip and strike; but it is proportionately high, with the rocks dipping steeply, nearly vertically in the middle. Upon each side is a narrow and very deep valley, almost a canyon, beyond which a higher and longer mountain rises very precipitously. The Logan or McGue Mountain upon the south appears to be a monocline here, with a dip of S. 27° E., while the Broken Rock Mountain upon the north seems to dip in the opposite direction. The beds exposed in Crystal Mountain are at the center of the fold, the quartz series being prominent. The outlying ridges carry the grits, and the underlying shales are exposed in the gorges at the base of the section.

Accident Ore.—At Witherspoon's, west of Crystal Mountain, near a blacksmith shop by the side of the road, a small excavation has exposed a bed of "accident ore." It has here the same characteristics as at the Phœnix Company's tunnel, and in many other places in Montgomery county. From developments at these points, and from other observations southward, the relations of this rock have been clearly determined. There is no doubt that it lies in the millstone grit, above the tougher and more thickly bedded members of the tripartite shales, and in rather close relations with the dolomitic rocks of the former series.

THE SILVER CITY MINING AREA.

Those tributaries of the south fork of the Ouachita river, which flow northward through 2 S., 23 W., and 2 S., 24 W., drain all the mining territory of the Mt. Ida district. The half-dozen properties upon which the mining industry has been mainly dependent lie in a tract less than four miles square, although a somewhat larger area has been prospected very thoroughly. It is doubtful whether any great interest could have been awakened in precious metal mining in Arkansas without some such indications of mineral wealth as occur in this particular region. The belief that a large portion of the State is capable of producing gold or silver, or both these metals, appears to have been derived largely from the success of the explorations made in the mines near Silver City. This idea is based largely upon the fact that the country rocks at Silver City are the same as those which occur over the regions for many miles around. It was supposed that if these rocks, the shales, quartz beds, and the millstone grits, were the depositories of the precious metals, then at least twelve counties, embracing a territory of more than 10,000 square miles, would be one vast gold and silver mine. Not all these strata, however, carry the metals in paying quantities. The source of the metallic ores is a very limited group of special deposits, which represent intensified hot spring action in the past.

The Rubicon Mining Co.—This company, incorporated under the laws of Illinois, owns the Eureka, Virginia, Rubicon and Montrose mining claims, which have been worked by shafts and tunnels. The openings are made near the water level in the narrow bottom land along the course of a branch of Walnut creek, in sections 25 and 26, 2 S., 23 W. A town site, known as Virginia City, has been laid out here. The Eureka and Virginia shafts are upon opposite sides of the creek, only a few rods apart, and the two claims are sometimes mentioned as the Consolidated Virginia mine. On July 25, 1887, the west shaft was down about twenty-eight feet, with a drift at the bottom, and the east shaft was thirty feet in depth. The country rock is black shale, similar, in nearly all respects, to that of the Ozark mine. Seams of quartz penetrate the rock here, and a number of these may be seen along the sides of the ravine, on both sides of the shaft. There is a semblance of vein structure, with considerable quartz in the shaft, and patches of galena, pyrite, etc., with much zinc blende occurring here and there in the quartz. A small quantity of the ore lay upon the dumps, but by far the greater portion of the product has been graphitic shale. The "blue mud" already described is abundant here.

There has been too little development upon these claims to warrant assertions as to the value of the property.

The Broken Rock Belt.—The general aspect of the country northwest of the Eureka mine, as far as the bluffs bordering the south fork of the Ouachita, is somewhat rugged, the topography being very much like that in the neighborhood of the Ozark mine. The rocks appear to represent the tripartite shales for the most part, but the higher sand-rock, and a little of the overlying quartzite, cap the the hills in places. Much of the region has been modified by erosion and by the deposition of lacustrine gravels, which obscure the structure. A minute survey will be necessary to elucidate all the doubtful points in the geology. Northwest of the Eureka mine, detrital deposits and irregular erosion make it difficult, in a rapid trip, to connect the scattered observations into a consistent section. The general dip, over this area, is southward, and the northward flowing streams cut down through the shale series. There is the least difficulty, considering all known facts, in explaining the very peculiar drainage of this region by the hypothesis of a fault trending approximately in the general course of the South fork. If this be true, probably it will be found that the line of fracture is farther south than the present bed of the river. There is a long line of disturbance, which passes through this district, extending as far southwest as Sevier county. Elsewhere it has been studied in several places, and much of economic importance has been developed thereby. This axis passes near Broken Rock Mountain, thence southwestward through Logan gap, in a course which will be outlined in the next chapter, under the heading of "Broken Rock Axis." In traveling from a point east of Logan gap to Forbes's, in a northwestern line, and then northeastward to Silver City, some indications of an anticline were observed. From facts gleaned in other localities, the conclusion is reached that the rocks are contorted or badly broken and faulted, along that portion of the fold which lies north of the long ridge, but they are less affected southward. The Eureka mine and its neighbors are not far from this "Broken Rock Axis."

The Walnut Mine.—Near the mouth of Walnut creek, about on the line between sections 17 and 20, 2 S., 23 W., there is a shaft 183 feet in depth, with a drift, as reported, from one side. The mine, when visited, was filled with water to within twelve feet of the floor of the shaft house, but the very large dump, and a good exposure of the rocks in the neighborhood, afford opportunities for study. The ore is contained in a fairly defined banded vein of quartz and calcite. A section across the whole shows talcose schist upon the hanging wall, firmly united to a band of quartz several inches in thickness, to which is attached a thick seam of coarsely crystalline calcite. Feeders run off into the country rock, which is here the black shale, presumably near the base of the series. In places there are pockets of the quartz and calcite irregularly mingled. Occasionally patches of galena, chalcopyrite, and sphalerite occur in the mass, but these do not seem to be very abundant. The conditions are very similar to those surrounding the Minnesota mine to be described beyond, except that there they are much magnified. The workings had been abandoned at the time of the writer's visit, and there was no means of estimating the economic value of the deposit in which the Walnut mine is opened. The vein is of moderate size, and of a structure indicating good conditions for mineral deposition, provided that a suitable source of supply is in the subjacent rocks. But unless comparatively large pockets of high grade ore be struck in the deep workings, the proportion of barren rock that it will be necessary to raise will be too large to leave any profit. The dip of the shales is below 30° S., 31° E. The vein cuts through these at a high angle, in a nearly east-west course. For assays of material from this mine, consult Table 1. The topography of the vicinity is interesting. The valley of the south Ouachita winds picturesquely between high banks, which have been much modified and rounded by erosion and subsequent alluvial deposition. The stream courses which join from the south, have rapid grades, and the hill-sides, and even the hilltops, present many examples of locally developed quartz bodies which may have been caused by hot spring action.

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The country west of Silver City, to and beyond Mt. Ida, is, for the most part, a broad, flat tract covered with detrital deposits, the bed rock being, presumably, the upper portion of the tripartite shales, the terrane which carries the vein of the Eureka mine. The widest portion of the great basin of the South fork is adjacent to the McKinney settlement, and extends southward. East of this stretch, the valley continues into the narrows caused by the resistance of the quartzites to eroding agencies, the underlying shales having been protected by the hard caps which now form the summits of the ridges and knolls.

South of the main valley of the South fork of the Ouachita, the tributaries rise but short distances from the river upon the

flank of a long, precipitous ridge, known as the McGue Mountain, or Logan Mountain. There is no water gap in this ridge for thirty-five miles. It does not follow a structural line, but represents the resistance to erosion of the hard quartzites and grits.

The Blue Mountain Fold.—The dip changes to N., 27° W., between Silver City and Mt. Ida, the axis of the anticline being nearly in the average course of the South fork through township 2 S., 23 W. This trend carries the axis diagonally across the basin to the vicinity of the gap southeast of Mt. Ida, from which a branch of Rattlesnake creek flows off southeastward. Across the southwestern portion of Montgomery county this fold can be more readily traced. There is every indication at the Montezuma mine, which is almost directly in the line, that a fault has occurred, the "downthrow" upon the northern side having brought the upper members of the tripartite shales to the level of the red shales of the lower division.

Mt. Ida.—The town of Mt. Ida is situated upon a gravel terrace of the ancient river or lake, apparently at the mouth, or in the course of a tributary stream from the south. The former topography has been obscured by thick deposits of water-worn debris. A section shown by the excavation of a well south of the town exposes twenty feet of cemented gravel, underlain by the black shales dipping 40° N., 27° W. Seams, or interstratified layers of graphitic shale, with bands of pure white calcite, are abundant. The black shale resembles some of the higher members of the tripartite series. Southwest of Mt. Ida, on the Black Spring road, the same shales appear with much quartz in depressed areas, with quartzites or grits capping the low mountains. The dip continues constant in direction, but falls off to 35° in the upper beds of the section.

CHAPTER X.

Montgomery County Continued.—South Half.

In order to understand the geologic section and the topography of the region south of the long ridge that hems in the Ouachita drainage upon the south, it is necessary to return to the southeast corner of Montgomery county and trace out the structure westward from the west line of Hot Spring and Garland counties.

The Sugar Loaf Anticline.—The Sugar Loaf anticline, prolonged southwestward from Garland county, passes across the southeastern portion of Montgomery county and diagonally through the northernmost fourth of Pike county.* This axis is exposed near the southwest corner of Garland county, in sections 7 and 8, 4 S., 22 W. From this point it trends in a line which runs approximately through township 4 S., 23 W., by way of sections 12, 13, 14, 15, 22, 20, 29, 30, and thence to the south line of Montgomery county at the southeast corner of section 33, 4 S., 24 W. In Montgomery county this fold acts largely as a water-shed, but its influence upon the general drainage is not marked. The Caddo, after crossing it, joins Caney creek, which has also cut through it, and then the Trap Mountain drainage materially alters the direction of the flow.

East of Mazarn Mountain and the Narrows, in townships 3 S., and 4 S., 23 W., the Big Mazarn has a comparatively broad valley. At the east line of Montgomery county, section 1, 4 S., 23 W., the river is in the black shales in places, but over a large part of the area. the alluvium is so thick that the stream flows high above its ancient bed. There is a large amount of quartzose debris in terraces, and irregular, rounded knolls, with black, miry soil in the bottoms. Where exposures can be found in this region, the quartz horizon is usually within the shale series. Near the line, probably in the western edge of Garland county, at the mouth of a little rivulet, upon the south bank of the river, several intercalated beds of quartzite, or of very tough quartz, stand up like dikes across the creek bed, the softer shales having been eroded so as to leave pools between the hard beds. The dip is S., 27° E., 40° to 50. Not far below this point, the Mazarn turns into the strike of the beds; and above this in section 2, 4 S , 23 W., it has a trend in somewhat different rocks.

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*The writer crossed this fold in Pike county in two places. Its course through Montgomery county is here laid out by filling in the gaps.

The Mazarn Anticline. – The Mazarn anticline leaves Garland county in section 31, 3 S., 22 W., and bears across Montgomery county to the south line of sections 36 or 35, 4 S., 25 W. Its approximate course is through section 36, 3 S., 23 W., thence through sections 1, 2, 3, 9, 8, 18, 4 S., 23 W., thence through sections 13, 14, 23, 22, 21, 28, 29, 30, 31, 4 S., 24 W., to section 36 or 35, of 4 S., 25 W.* The south branch of the Mazarn follows this axis closely in sections 2 and 3, 4 S., 23 W.

There is another remarkable difference between the topography of Garland and Hot Spring counties and this portion of Montgomery county. In those areas, there are several large streams, including a considerable length of the Ouachita river, which follow old structural lines. In Montgomery county this following of structural lines is of rare occurrence in important water courses. It is also interesting to observe that in all that part of the hydrographic basin of the Ouachita river above Arkadelphia, wherever this stream, or any of its tributaries, follows a course coincident with the strike of the beds, it almost invariably runs in black shales. This peculiarity is not confined to the Ouachita drainage, but it is more noticeable over that area.

In Montgomery county, the great backbone divide, which walls in the South fork, is succeeded upon the south by other tough rocks, and through some cause, not yet clearly elucidated, the drainage of the southern portion of the county is

decidedly different from that of the adjoining areas upon the east and west. This may be explained in part by tracing the shale axis of the fold, which traverses the heart of the Silver City mining belt, and which crosses the long ridge at Logan gap. The gap itself is largely due to the more rapid erosion of the shales than of the quartzites and grits. The Walnut gap, much farther east, has had a similar origin, and, speaking geologically, Blue creek starts off from it southwestward, in the line of the strike, precisely as Rattlesnake creek flows from the vicinity of Logan gap.

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*This anticline was also crossed in Pike county in section 3, 5 S., 25 W., and in section 14, 5 S., 26 W.

The Golden Wonder Anticline.—Approaching Logan gap from the southeast, after crossing the Mazarn anticline, the rocks dip N., 27° W. for a little distance, changing in section 25 or 24, 3 S., 23 W., and exposing another anticline in sections 23 and 24 This is undoubtedly the prolongation of the "Golden Wonder" axis, as it is directly in the course of that fold between the Golden Wonder mine and Caddo gap, at both of which localities it has been studied. The character of the rocks exposed here is not the same as at the other places, but there has been much more erosion, and the detrital deposits largely obscure the structure. The style of erosion is different from that observed at any other point along this axis, the fold being cut across and denuded by the ancient Mazarn river. Besides the observations upon this axis in the Glazypool valley in Garland county, and those which have been mentioned, its outcrop was noticed at points in Pike and Howard counties, where it follows the same course. Through Montgomery county, it trends from the northeast quarter of section 24, 3 S., 23 W., through sections 23, 26, 27, 33, 32, across sections 6, 4S., 23 W., thence through 4 S., 24 W., by way of sections 1, 12, 11, 15, 16, 20, 19, and on to the north line of Pike county through sections 25, 26 and 34, 4 S , 25 W.

Some discussion of the Golden Wonder axis, as it crops out at Caddo gap, has been given in chapter VIII. The peculiar structure observed there and elsewhere along this trend, is apparently persistent, and not merely a local contortion. It is more like a double turn in the strike of the beds than a simple

been awakened in precious metal mining in Arkansas without some such indications of mineral wealth as occur in this particular region. The belief that a large portion of the State is capable of producing gold or silver, or both these metals, appears to have been derived largely from the success of the explorations made in the mines near Silver City. This idea is based largely upon the fact that the country rocks at Silver City are the same as those which occur over the regions for many miles around. It was supposed that if these rocks, the shales, quartz beds, and the millstone grits, were the depositories of the precious metals, then at least twelve counties, embracing a territory of more than 10,000 square miles, would be one vast gold and silver mine. Not all these strata, however, carry the metals in paying quantities. The source of the metallic ores is a very limited group of special deposits, which represent intensified hot spring action in the past.

The Rubicon Mining Co.—This company, incorporated under the laws of Illinois, owns the Eureka, Virginia, Rubicon and Montrose mining claims, which have been worked by shafts and tunnels. The openings are made near the water level in the narrow bottom land along the course of a branch of Walnut creek, in sections 25 and 26, 2 S., 23 W. A town site, known as Virginia City, has been laid out here. The Eureka and Virginia shafts are upon opposite sides of the creek, only a few rods apart, and the two claims are sometimes mentioned as the Consolidated Virginia mine. On July 25, 1887, the west shaft was down about twenty-eight feet, with a drift at the bottom, and the east shaft was thirty feet in depth. The country rock is black shale, similar, in nearly all respects, to that of the Ozark mine. Seams of quartz penetrate the rock here, and a number of these may be seen along the sides of the ravine, on both sides of the shaft. There is a semblance of vein structure, with considerable quartz in the shaft, and patches of galena, pyrite, etc., with much zinc blende occurring here and there in the quartz. A small quantity of the ore lay upon the dumps, but by far the greater portion of the product has been graphitic shale. The "blue mud" already described is abundant here.

There has been too little development upon these claims to warrant assertions as to the value of the property.

The Broken Rock Belt.—The general aspect of the country northwest of the Eureka mine, as far as the bluffs bordering the south fork of the Ouachita, is somewhat rugged, the topography being very much like that in the neighborhood of the Ozark mine. The rocks appear to represent the tripartite shales for the most part, but the higher sand-rock, and a little of the overlying quartzite, cap the the hills in places. Much of the region has been modified by erosion and by the deposition of lacustrine gravels, which obscure the structure. A minute survey will be necessary to elucidate all the doubtful points in the geology. Northwest of the Eureka mine, detrital deposits and irregular erosion make it difficult, in a rapid trip, to connect the scattered observations into a consistent section. The general dip, over this area, is southward, and the northward flowing streams cut down through the shale series. There is the least difficulty, considering all known facts, in explaining the very peculiar drainage of this region by the hypothesis of a fault trending approximately in the general course of the South fork. If this be true, probably it will be found that the line of fracture is farther south than the present bed of the river. There is a long line of disturbance, which passes through this district, extending as far southwest as Sevier county. Elsewhere it has been studied in several places, and much of economic importance has been developed thereby. This axis passes near Broken Rock Mountain, thence southwestward through Logan gap, in a course which will be outlined in the next chapter, under the heading of "Broken Rock Axis." In traveling from a point east of Logan gap to Forbes's, in a northwestern line, and then northeastward to Silver City, some indications of an anticline were observed. From facts gleaned in other localities, the conclusion is reached that the rocks are contorted or badly broken and faulted, along that portion of the fold which lies north of the long ridge, but they are less affected southward. The Eureka mine and its neighbors are not far from this "Broken Rock Axis."

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near the natural outcrop of the red and yellow soft sandstone of the grit series.

The value of this widespread bed as an iron ore has not been determined. Judging from appearances, it is too highly siliceous to be profitably utilized. It has no value whatever as an ore of the precious metals.

Going down the southern slope of the mountain over the Lick creek drainage area, one passes successively through the lower grits and the quartzites to the quartz series, and finally into the black shales beneath.

Black Spring.—In the northern edge of the town of Black Spring the road crosses a little run in which the black shales are imperfectly exposed, the alluvial deposits of the ancient Caddo having obscured the rock formations. The rocks through this region, west of the line of the anticline, dip N., 27° W., 30° to 35°. The shales seem to lie near the base of the quartz-bearing division. The water which flows from these shales is agreeable to the taste, slightly charged with sulphur, and is diuretic. It is held in high esteem for its medical properties by the people of the neighborhood.

Sloane's Alum Well.—On the southeast quarter of section 31, 3 S., 25 W., at Mr. Sloane's house, there is a deep well, opened in the black shale, the water from which cannot be regularly used because of its strong taste. When the supply is plentiful, as it was August 11, 1887, it is slightly astringent, and has the taste of a rather sour chalybeate water; but in a dry period the solution becomes highly concentrated and unsuitable for drinking purposes. Half a gallon of water, taken at the time of its greatest strength, and evaporated, produced a reddish brown powder, perhaps two ounces or more in weight. A qualitative analysis of this sample shows:

Iron (ferrous), Magnesium,
Sulphuric acid, Potassium,
Aluminium—very slight trace.

The line of the Blue Mountain uplift passes near this locality, and the topography at Mr. Sloane's, and between there and Black Spring, suggests that the fracture may run directly through his farm. The altitude at Mr. Sloane's is greater than at the town, and the beds of shale which supply the water are probably higher in the geologic scale than those at Black Spring.* If this water should prove, medicinally or otherwise, economically valuable, it is probable that an abundance of it can be found at slight depths by boring under the guidance of a competent geologist.

FROM BLACK SPRING TO CADDO GAP.

East of Black Spring village the dip of N., 27° W., 35° continues almost to the axis of the Blue Mountain fold, where the red shales appear, followed by beds of black shale dipping 60° S., 27° E. No change in this dip was noticed, except in amount, until the contortions, which represent the Broken Rock axis, were reached in section 34.

Mining Claims.—There have been some attempts at mining at different points upon the southern dip, between the two folds mentioned. One of these is in the shales north of the road on the left bank of Lick creek, one mile and a half east of Black Spring. Another excavation of some importance was made much nearer the Broken Rock line. Neither of these has yielded satisfactory results, and nothing is to be expected of either one, unless the red shales below those on Lick creek shall be found to contain enough iron to pay the cost of handling and smelting.

The tough grits of the quality known northward as "accident ore" have few natural outcrops in the lowlands, because the soils and alluvial deposits cover them extensively. Leaving the road at Owen Robbins's house, on section 28, and going south and east, across the Caddo, then following a dim road less than half a mile, one finds a shaft 15 feet by 7 feet, and 12 feet deep, in which the following section is exposed from the surface downward:

1. Reddish yellow clay loam, 3 to 4 feet.

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*Compare this situation with that described in section 14, 1 N., 28 W., where the proprietor has made commercial use of it.

2. Black, hard shale, 8 feet at thickest part (southeast corner of the shaft), thinning across the shaft, where it is underlain by

3. "Accident ore," a tough, dark grit, resembling part of the product from the Accident tunnel of the Phœnix Mining Company, 2½ feet.

4. Thickly bedded, greenish gray grit, in the bottom of the shaft.

There is no real ore, nor any sign of a vein or special deposit, exposed. Similar and other rocks, all dipping alike, occur in the bed of the stream, only a few rods distant. The difference in the exposure on the two ends of the excavation is due to the dip, while the thinning of No. 2 is plainly the result of denudation. Crossing the country from this point to the main road near Wm. Reeves's, in sections 27 and 34, much scattered sandy rock is visible; but a geologic section is not readily made out in detail. There seems to be a regular and gradual passage into the higher quartzitic sandstones, such as are well exposed in McGue Mountain east of Logan gap.

Mr. Reeves, without knowing the results of the writer's work, gave much detailed information which helps to confirm the opinions expressed concerning the geology of this district. He had some good ironstone nodules, which came from the wash of a hill in the northern part of section 27, 3 S., 25 W., near an exposure of what he calls "accident ore." This gentleman also has a good collection of crystals, quartz, some specimens containing bubbles or water cavities; these he accredits to a position in the line of the Broken Rock axis, thus establishing more firmly the idea of a disturbance in that belt.*

The Gray Eagle axis probably passes not far from Vaught's Mill, in the northwest quarter of section 18, 4 S., 24 W. This fold is one of the most difficult to trace, and the valley of the

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*Many specimens of galena, pyrite, limonite, pyrolusite, etc., were shown by Mr. Reeves. These, he says, were obtained by him on the head waters of the Little Missouri, on the dividing ridge between the head waters of Crooked creek and those of the Caddo. The associated rocks exhibited by him are of the millstone grit series, and the ores resemble those of the Silver Hill district in Sevier county.

There has been too little development upon these claims to warrant assertions as to the value of the property.

The Broken Rock Belt.—The general aspect of the country northwest of the Eureka mine, as far as the bluffs bordering the south fork of the Ouachita, is somewhat rugged, the topography being very much like that in the neighborhood of the Ozark mine. The rocks appear to represent the tripartite shales for the most part, but the higher sand-rock, and a little of the overlying quartzite, cap the the hills in places. Much of the region has been modified by erosion and by the deposition of lacustrine gravels, which obscure the structure. A minute survey will be necessary to elucidate all the doubtful points in the geology. Northwest of the Eureka mine, detrital deposits and irregular erosion make it difficult, in a rapid trip, to connect the scattered observations into a consistent section. The general dip, over this area, is southward, and the northward flowing streams cut down through the shale series. There is the least difficulty, considering all known facts, in explaining the very peculiar drainage of this region by the hypothesis of a fault trending approximately in the general course of the South fork. If this be true, probably it will be found that the line of fracture is farther south than the present bed of the river. There is a long line of disturbance, which passes through this district, extending as far southwest as Sevier county. Elsewhere it has been studied in several places, and much of economic importance has been developed thereby. This axis passes near Broken Rock Mountain, thence southwestward through Logan gap, in a course which will be outlined in the next chapter, under the heading of "Broken Rock Axis." In traveling from a point east of Logan gap to Forbes's, in a northwestern line, and then northeastward to Silver City, some indications of an anticline were observed. From facts gleaned in other localities, the conclusion is reached that the rocks are contorted or badly broken and faulted, along that portion of the fold which lies north of the long ridge, but they are less affected southward. The Eureka mine and its neighbors are not far from this "Broken Rock Axis."

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The Mazarn Anticline.—The Mazarn anticline leaves Garland county in section 31, 3 S., 22 W., and bears across Montgomery county to the south line of sections 36 or 35, 4 S., 25 W. Its approximate course is through section 36, 3 S., 23 W., thence through sections 1, 2, 3, 9, 8, 18, 4 S., 23 W., thence through sections 13, 14, 23, 22, 21, 28, 29, 30, 31, 4 S., 24 W., to section 36 or 35, of 4 S., 25 W.* The south branch of the Mazarn follows this axis closely in sections 2 and 3, 4 S., 23 W.

There is another remarkable difference between the topography of Garland and Hot Spring counties and this portion of Montgomery county. In those areas, there are several large streams, including a considerable length of the Ouachita river, which follow old structural lines. In Montgomery county this following of structural lines is of rare occurrence in important water courses. It is also interesting to observe that in all that part of the hydrographic basin of the Ouachita river above Arkadelphia, wherever this stream, or any of its tributaries, follows a course coincident with the strike of the beds, it almost invariably runs in black shales. This peculiarity is not confined to the Ouachita drainage, but it is more noticeable over that area.

In Montgomery county, the great backbone divide, which walls in the South fork, is succeeded upon the south by other tough rocks, and through some cause, not yet clearly elucidated, the drainage of the southern portion of the county is

decidedly different from that of the adjoining areas upon the east and west. This may be explained in part by tracing the shale axis of the fold, which traverses the heart of the Silver City mining belt, and which crosses the long ridge at Logan gap. The gap itself is largely due to the more rapid erosion of the shales than of the quartzites and grits. The Walnut gap, much farther east, has had a similar origin, and, speaking geologically, Blue creek starts off from it southwestward, in the line of the strike, precisely as Rattlesnake creek flows from the vicinity of Logan gap.

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The Walnut Mine.—Near the mouth of Walnut creek, about on the line between sections 17 and 20, 2 S., 23 W., there is a shaft 183 feet in depth, with a drift, as reported, from one side. The mine, when visited, was filled with water to within twelve feet of the floor of the shaft house, but the very large dump, and a good exposure of the rocks in the neighborhood, afford opportunities for study. The ore is contained in a fairly defined banded vein of quartz and calcite. A section across the whole shows talcose schist upon the hanging wall, firmly united to a band of quartz several inches in thickness, to which is attached a thick seam of coarsely crystalline calcite. Feeders run off into the country rock, which is here the black shale, presumably near the base of the series. In places there are pockets of the quartz and calcite irregularly mingled. Occasionally patches of galena, chalcopyrite, and sphalerite occur in the mass, but these do not seem to be very abundant. The conditions are very similar to those surrounding the Minnesota mine to be described beyond, except that there they are much magnified. The workings had been abandoned at the time of the writer's visit, and there was no means of estimating the economic value of the deposit in which the Walnut mine is opened. The vein is of moderate size, and of a structure indicating good conditions for mineral deposition, provided that a suitable source of supply is in the subjacent rocks. But unless comparatively large pockets of high grade ore be struck in the deep workings, the proportion of barren rock that it will be necessary to raise will be too large to leave any profit. The dip of the shales is below 30° S., 31° E. The vein cuts through these at a high angle, in a nearly east-west course. For assays of material from this mine, consult Table 1. The topography of the vicinity is interesting. The valley of the south Ouachita winds picturesquely between high banks, which have been much modified and rounded by erosion and subsequent alluvial deposition. The stream courses which join from the south, have rapid grades, and the hill-sides, and even the hill-tops, present many examples of locally developed quartz bodies which may have been caused by hot spring action.

The Montezuma Mine.--Very similar in many respects to the preceding, but with other essentially different features, is a large exposure high up the steep mountain side, near the middle of the line between sections 16 and 17, 2 S, 23 W. This, formerly worked as the Montezuma mine, but now abandoned, consists of an immense mass of quartz protruding from a bank of talcose slates. Through the quartz are imbedded crystals of the same material. Some of these crystals are very large and perfectly formed, and beautiful examples of twinning are frequent. The slates dip S., 31° E., 25°. The relations of the quartz to the enclosing rocks are not readily discernible, but this seems to be due to mere local accumulation in the form of an irregular mound. The mining development, July 25, 1887, consisted of a shaft ninety feet in depth and an adit of 100 feet starting at the level of the shaft mouth. The shaft was full of water, and the adit level was seriously obstructed by debris from the roof. No ore appears upon the surface. A small quantity of selected mineral was in the ore-house. This ore is of a character well worth pursuing, as it carries considerable lead and some high grade silver minerals.

Silver City.—In section 30, 2 S., 23 W., the development of the few mines in the district led to great expectations, and a small but admirably planned town site was laid out at a convenient point for a base of supplies.

The Minnesota Mine.—At the eastern end of the town of Silver City, and upon the main road from Hot Springs to Mt. Ida, there is a great deposit of quartz in a ledge which is also covered by quartz "float." The first mining work done was upon a collection of the float quartz in a little run south of the road. From the proceeds of this, which contained some rich ore like tetradedrite, enough inducement was obtained to warrant further explorations. A large shaft was therefore sunk a few rods east of the discovery, and afterwards the vein was disemboweled wherever it gave promise of remuneration. It is reported that very handsome returns were received from this early work. The bonanza soon gave out, however, and no new ore-bodies were discovered. An attempt was made to

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develop the property by running a gallery northward from the shaft. This yielded nothing and the mine was finally abandoned. Scarcity of funds and lack of machinery to cope with the water have prevented further progress. Decay has set in, so that it is doubtful whether any use could be made of the old workings by any one who might undertake to work the mine. The rocks adjoining dip S., 31° E. from 22° to 44°. The quartz appears to be lying mostly in stratification planes coincident with the shales, except in the external mound. So far as can be judged from what is known, the proper method of exploration would be to follow down the vein towards the south. The shaft has probably cut entirely through the deposit into the country rock. A slope of 45° would be more likely to continue in ore. Some of the quartz shows small patches of galena, and in places there are soft greenish and reddish inclusions. These are locally known as "bromides" and "chlorides," but they resemble products of the decomposition of pyrite, i. e., sulphur and iron oxide. There is not so much vein structure here as at the Walnut mine, but the quartz and calcite are much more abundant. These minerals occur in parallel bands, often separated by several inches of a tough, dark quartzite to which they are cemented. This property ought to be more thoroughly and systematically explored.

The Waterloo Mine.—Half a mile northwest of Silver City some mining work has been done in an area whose topography is strikingly similar to that of the portions of Yellowstone Park in which the hot springs are most abundant. The workings of the Waterloo were abandoned when the writer visited them. There is an old shaft, 7 by 9 feet, said to be fifty feet in depth, but this was half filled with water in July, 1887. The surface formations consist of irregularly disposed soft sands and clays of variegated colors. These are underlain by shales which have some of the characteristics of those which underlie the sinter deposits in the Sand Carbonate mine, near Blocher. Other facts gleaned in the study of this region suggest that the horizon of the Silver City district is not very dif-

ferent from that of the Blocher tract. Probably, however, the Waterloo mine is higher in the series. The shales are black and laminated above but talcose and thinly foliated below. The talc shale horizon is persistent, and may form a good geologic guide to future workers, as it is exposed in several widely separated localities west of this district. It has a peculiar glistening appearance, due to its fine grained texture.

In a little ravine west of the shaft-house the owners of the Waterloo have cut a deep and narrow trench to crosscut the vein which bears southwestward. At the north end of the trench the vein was struck and the cross-cut was continued upon it under cover for ten feet. This exposure of the vein, although it affords no criterion for estimating the value of the property, gives, in connection with the history, presumptive evidence which is favorable. The ore exposed is not extensive, and apparently not high grade; but, if enough can be procured, it will smelt fairly well. The silver is apparently in the form of tetrahedrite or a similar mineral. Galena with pyrite, a small proportion of chalcopyrite, and considerable zinc blende, make up the mass of the ore, but this occurs in pockets rather than in well defined streaks. Feeders from the vein run out irregularly into the underlying shale. Owing to the local superficial deposits there is little chance to observe the country rock above.

The country west of Silver City, to and beyond Mt. Ida, is, for the most part, a broad, flat tract covered with detrital deposits, the bed rock being, presumably, the upper portion of the tripartite shales, the terrane which carries the vein of the Eureka mine. The widest portion of the great basin of the South fork is adjacent to the McKinney settlement, and extends southward. East of this stretch, the valley continues into the narrows caused by the resistance of the quartzites to eroding agencies, the underlying shales having been protected by the hard caps which now form the summits of the ridges and knolls.

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crumpling parallel to the fold. Its occurrence at several widely separated points in this axis, and a nearly similar example of this structure thirty-five miles away from the line of these exposures, make this explanation seem more reasonable. Something not unlike this was also observed in the Golden Wonder mine, but there was no opportunity to study the matter. At that point, however, a decided change in the rocks occurs. The structure apparently implies the exertion of force upon rocks in a more or less plastic condition, but one feature of the Golden Wonder quartz is its minutely jointed character, and this is the case with nearly all the rocks associated with it. The higher members are less affected than those nearest it. Besides, it does not appear that the same section is given by all the transverse cuts through this fold. Putting together all these facts, and bearing in mind the remarkable effect of this and the Gray Eagle axis upon the topography along their parallel courses, no explanation suggests itself that consistently includes the whole any better than the supposition of the existence of lines of fault or of slipping of the strata along stratification planes. At the same time, the regularity and continuity of the folds south and west of Montgomery county give no strong support to such an idea. If there be faults, each has probably an axial trend, and the dislocations have been subsequent to the folding of the strata. This hypothesis affords quasi explanations of a number of puzzling facts, and it may account for the topography and the drainage features in a large measure.

The Mazarn Mountain and the neighboring elevations are interesting features in the topography. The Golden Wonder axis crosses them very much as the folds traverse the ridges of the Trap Mountains southeastward in Hot Spring county. For the most part, the rocks are higher in the geologic scale in Montgomery county, and the erosion has, therefore, been different, while the water courses have cut the flexures less obliquely. The formations that are vertical in the axis west of the Grand Mazarn basin are more durable, the folds are broader, and the outer beds dip less steeply, all of which features have tended to increase the resistence to denudation. So far as can be, with these characteristics, the peculiarities observed in the Trap range are repeated in the ridges of southeastern Montgomery county. But this parallel gradually becomes inapplicable as one goes northwest beyond the Mazarn Mountain. The Golden Wonder belt, as is the case northeastward, foreshadows the transition to the rugged and unsymmetrical topography of the grits, by the quartzitic nucleus and the foothills or outliers, like the Mazarn Mountain, which appear upon both sides of the axis. The country along the course of the Big Mazarn in 3 S., and 4 S., 23 W., has been subjected to the action of vast currents of water at some remote period. Its valley is strewn with detritus, much of which bears evidence of transportation.

The Gray Eagle Belt.—At the crossing of Blue creek, on the Hot Springs and Dallas road, section 22, 3 S., 23 W., there is an exposure of the black shales, with interclated layers of the quartzose rock in the bed of the stream, which have a steep dip S., 27° E. The water has cut out the shales, making pools between the hard beds, which stand out like dikes, as in the case described near the Mazarn anticline.

The "Black Mud" Deposit.—Below these shales in the geologic section, but farther up the creek, the graphitic shales appear. In the northwest quarter of section 22, back of Bud Jones's house, which stands in the northeast corner of section 21, a little prospecting has been done. A small quantity of soft black earth has been taken from a pit in the bank of the creek. It is supposed to be the "black mud" that has caused the excitement at Bear City. The material is the same, and has as little value here as there, being nothing more than finely comminuted graphitic shale. The horizon of this bed is near the top of the tripartite shales, and the rock is not abundant or very highly charged with graphite.

Blue creek follows the general course of the Gray Eagle belt, but it is not in the axis of the fold except near its mouth in section 22, where the road crosses it. The prolongation of this line southwestward along the strike follows the divide between the Mazarn and the Caddo, and passes out of Montgomery into Pike county near the southeast corner of section 36, 4 S., 26 W. It was again crossed in section 8, 4 S., 24 W., and in Howard county the extension of this axis is plainly shown in the valley of an east branch of the Saline river.

The Accident Anticline.— In the north half of section 17, 3 S., 23 W., the Big Mazarn flows northeast for some distance in the strike of the rocks, following closely the axis of a fold corresponding in all particulars with the Accident anticline described in chapter VIII. The rocks known as the Accident ore of the grit series, are exposed in a nearly vertical position in Little Mountain, where the road to Logan gap crosses the Mazarn in section 17. The two sides of the fold appear in outcrops south and north of the crossing, and then a narrow syncline is followed by the southeastward dip of McGue Mountain, bringing to view those members of the millstone grit that overlie the "Accident ore" in the Phœnix Mining Company's property in the prolongation of the fold northeastward. The rocks of the section resemble very closely some of the dark grits of equivalent horizon in eastern Pennsylvania. They appear to lie not far below the blue dolomite horizon, which is exposed in the cliffs upon the northern side of Little Mountain, in section 7. Beyond the western edge of Little Mountain, a very considerable amount of fragmental quartzite has been deposited with belts of quartz debris. This region is part of the Caddo drainage, and the denuding agents have cut down deeply into the strata. Rattlesnake creek here follows the synclinal valley. The divide between the source of this stream and the head of the Mazarn, at Sangster's in the north half of section 7, 3 S., 23 W., is a low one.

Throughout the area just described, the environment corresponds in many respects with that in the neighborhood of the Accident fold in the upper hydrographic basin of a branch of the south fork of the Ouachita adjacent to the Accident tunnel.

The soutwestward continuation of this anticline crosses the route followed in Montgomery county, at only one point, but the axis was again defined in Howard county. East of the crossing of Rattlesnake creek by the road from Black Spring to Caddo gap, in section 1, 4 S., 25 W., there are indications of a fold with the same strike as this. The outcrop was not thoroughly examined; for the erosion and the subsequent deposition of detritus have very much obscured the structure in that region. However, from the observations made along the road, it may be safely inferred that the fold passes here. The topography is not exactly like that seen northward, but resembles it quite as much as would be expected under the changed conditions in the lower valley of Rattlesnake creek. Of the large number of anticlines traversing this county, there is no other with which it so nearly agrees. The line of the fold passes into Pike county near the northeast corner of section 5, 5 S., 26 W.

The Broken Rock Axis.—A line drawn from the valley of Little Blakely creek, in Garland county, by way of Logan gap, nearly through Cedar Glades in Montgomery county, to the headwaters of the Saline river in the northeastern portion of Howard county, and through Sevier county, by the way of Jordanbrook Post-office, will give a very close approximation of the course of the Broken Rock anticline.

The characteristics of the many folds already described are not prominent in any portion of this belt, nor are the structural features very striking.

The only place in which the route traveled lay far enough west to cross this axis in Montgomery county, was in section 35 or 36, 3 S., 25 W., on the Black Spring road from Hot Springs. Here the rocks are much contorted, but no sign of a reverse dip beyond was observed. Farther south, in Sevier county, the beds are similarly twisted, and the anticlinal structure is more or less evident.

It is well worth noting that the Broken Rock axis is one of the most important mineral bearing belts of Arkansas. Manganiferous iron ores occur in the valley of Little Blakely creek in Garland county, near the Eureka mine, in the Broken Rock Mountain area in Montgomery county; and Mr. Reeves, who lives on the line between sections 27 and 34, 3 S., 25 W., has collected many nodules of rich ironstone from the adjacent country. Limonite ores are also abundant northeastward. These ores deserve careful study. The prolongation of the axis through the southwestern portion of Montgomery county has not been examined by the Survey. In Sevier county, stibnite, a valuable antimony ore occurs, while antimonial silver ores have been formed in the Broken Rock district northeast of Logan gap.

The tough, thick slates reported in the upper valley of Rattlesnake creek, which seem to overlie the "Accident ore" and to underlie the gray grits, are well exposed along this axis on section 1, 3 S., 24 W., a little southeast of McLean. McGue, or Logan Mountain, extends up into the hard quartzitic sandstones of the higher grits. These sandstones are exposed upon the northern side of the axis, in Blakely creek canyon northeast of Cedar Glades.

The Broken Rock axis leaves Montgomery county and enters Pike county near the southwest corner of section 36, 4 S., 27 W., passing near Fancy Hill and Lindon. On section 34, 3 S., 25 W., not far from Wm. Reeves's house, the rocks in this trend are much contorted and broken, and these features are characteristic of the belt wherever it has been studied.

The Extension of the Blue Mountain Fold and Fault.—At the first crossing of Lick creek on the cut-off road from Mt. Ida to Black Spring, an anticlinal axis is exposed in the black shales, presumably of the horizon of the beds visible along or near the Blue Mountain fold in 2 S., 23 W., as at the Montezuma mine. The glistening, fine grained talc shale, such as is exposed at the Waterloo mine, near Silver City, upon the southern slope of the fold, crops out along the road from Mt. Ida to Black Spring, not far from the summit in the gap. The dip is apparently the same here as at the mine, but the structure is much obscured by detritus, which seems to be a post-tertiary deposit made up, in a large measure, of the red and yellow sands of the grit series, which is still uneroded north and west of the fault line. The fault is coincident in direction with the fold.

The constant dip of N., 27° W., was observed over most of the road from Mt. Ida to Black Spring. This road does not cross the Blue Mountain axis except in the localities mentioned in the preceding paragraph. There is an exposure of the red shales in a nearly vertical position with a leaning towards the opposite dip, on the Hot Springs and Dallas road, about one mile east of Black Spring, on section 32, 3 S., 25 W. No other observations, worthy of mention, were made along this axis in Montgomery county, but very similar details were worked out near Silver Hill in Sevier county. This fold leaves Montgomery county near its southwest corner.

The direct road from Mt. Ida to Black Spring passes through a district which affords excellent opportunities for the study of surface geology, but which reveals but little of the earlier geologic history. The quartz bearing division of the shales is the prevailing stage north of the divide between the Ouachita and the Caddo, the quartzites gradually appearing as cappings upon the hills, followed by the lower grits in the more elevated ridges. The grits west of the Blue Mountain axis are apparently higher in the series than those east of this line at equivalent elevations. South of the long ridge, where the road runs near the supposed fault line, some steeply pitching, thinly bedded grits form sharply defined walls along the valley of a branch of Lick creek, which has cut a gap in them. This portion of the country has a mountainous aspect, but the slopes along the valleys are gradual and well covered with sandy deposits.

*The "Ficticious" Lode.**—At the side of the road in section 9, 3 S., 25 W., there is an old location stake bearing this title The only deposit in the neighborhood, which could be, by any possibility, regarded as mineral bearing, is the red earth exposed where the stake is set. This material is near the summit of a ridge, almost at the water divide, and it is apparently lives on the line between sections 27 and 34, 3 S., 25 W., has collected many nodules of rich ironstone from the adjacent country. Limonite ores are also abundant northeastward. These ores deserve careful study. The prolongation of the axis through the southwestern portion of Montgomery county has not been examined by the Survey. In Sevier county, stibnite, a valuable antimony ore occurs, while antimonial silver ores have been formed in the Broken Rock district northeast of Logan gap.

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*The name is given as it appeared upon the location notice upon the claim itself.

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FROM BLACK SPRING TO CADDO GAP.

East of Black Spring village the dip of N., 27° W., 35° continues almost to the axis of the Blue Mountain fold, where the red shales appear, followed by beds of black shale dipping 60° S., 27° E. No change in this dip was noticed, except in amount, until the contortions, which represent the Broken Rock axis, were reached in section 34.

Mining Claims.—There have been some attempts at mining at different points upon the southern dip, between the two folds mentioned. One of these is in the shales north of the road on the left bank of Lick creek, one mile and a half east of Black Spring. Another excavation of some importance was made much nearer the Broken Rock line. Neither of these has yielded satisfactory results, and nothing is to be expected of either one, unless the red shales below those on Lick creek shall be found to contain enough iron to pay the cost of handling and smelting.

The tough grits of the quality known northward as "accident ore" have few natural outcrops in the lowlands, because the soils and alluvial deposits cover them extensively. Leaving the road at Owen Robbins's house, on section 28, and going south and east, across the Caddo, then following a dim road less than half a mile, one finds a shaft 15 feet by 7 feet, and 12 feet deep, in which the following section is exposed from the surface downward:

1. Reddish yellow clay loam, 3 to 4 feet.

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*Compare this situation with that described in section 14, 1 N., 28 W., where the proprietor has made commercial use of it.

2. Black, hard shale, 8 feet at thickest part (southeast corner of the shaft), thinning across the shaft, where it is underlain by

3. "Accident ore," a tough, dark grit, resembling part of the product from the Accident tunnel of the Phœnix Mining Company, 2½ feet.

4. Thickly bedded, greenish gray grit, in the bottom of the shaft.

There is no real ore, nor any sign of a vein or special deposit, exposed. Similar and other rocks, all dipping alike, occur in the bed of the stream, only a few rods distant. The difference in the exposure on the two ends of the excavation is due to the dip, while the thinning of No. 2 is plainly the result of denudation. Crossing the country from this point to the main road near Wm. Reeves's, in sections 27 and 34, much scattered sandy rock is visible; but a geologic section is not readily made out in detail. There seems to be a regular and gradual passage into the higher quartzitic sandstones, such as are well exposed in McGue Mountain east of Logan gap.

Mr. Reeves, without knowing the results of the writer's work, gave much detailed information which helps to confirm the opinions expressed concerning the geology of this district. He had some good ironstone nodules, which came from the wash of a hill in the northern part of section 27, 3 S., 25 W., near an exposure of what he calls "accident ore." This gentleman also has a good collection of crystals, quartz, some specimens containing bubbles or water cavities; these he accredits to a position in the line of the Broken Rock axis, thus establishing more firmly the idea of a disturbance in that belt.*

The Gray Eagle axis probably passes not far from Vaught's Mill, in the northwest quarter of section 18, 4 S., 24 W. This fold is one of the most difficult to trace, and the valley of the

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*Many specimens of galena, pyrite, limonite, pyrolusite, etc., were shown by Mr. Reeves. These, he says, were obtained by him on the head waters of the Little Missouri, on the dividing ridge between the head waters of Crooked creek and those of the Caddo. The associated rocks exhibited by him are of the millstone grit series, and the ores resemble those of the Silver Hill district in Sevier county.

Caddo here forms a basin in the black shales, which adds to its obscurity. A quarter of a mile from Vaught's on the main road, there is a novaculite ridge, which may represent this fold. We are here getting, temporarily, away from the grits and down into the quartz bearing shales. The ridges are, in some respects, of the type of the Trap Mountain members, but they differ from those in important particulars, especially in the tendency to trend with the folds, and in the absence of iron ores from the sinter deposits. The whole mass of this outlying ridge at the gap, appears to be made up of siliceous sinter, gray, white, black, and pink, being the characteristic shades. Not far northeast, in the axial line, some iron sinter has been reported, but not in such abundance, or in as many layers as were seen eastward in the Trap Mountains. These features agree well with the Gray Eagle belt, northeast of Bear City. The structure of the novaculite (geyserite) is nearly identical with that now forming in the Yellowstone Park, and it very closely resembles that which was observed north of Magnet Cove, in Garland county. The action of hot springs is clearly indicated here.

From Caddo Gap to the County Line, Shield's Creek.—In the Caddo gap sintery layers are exposed for nearly half a mile, beginning with vertical dips in the Golden Wonder axis, and reducing to 75° S., 27° E., where the river is crossed on the road leading westward up the south fork of the Caddo. This stream, for several miles above its mouth, runs in the syncline between the Golden Wonder and the Mazarn anticlines. Along the road from Caddo Gap Post-office to Fancy Hill the siliceous sinters continue for about one mile, when the black shales are reached in the synclinal valley. The road then becomes very sandy. The Golden Wonder axis is much obscured by the enormous "wash" from the creek, but a reversal of the dip was noticed in section 25 or 26, 4 S., 25 W., after which synclinal dips were seen, and finally, upon section 28, the Gray Eagle anticline appears, faintly defined. The route pursued through this portion of the country was tortuous, as the road winds about among the hills. Southeastward from the crossing of South fork, the Golden Wonder anticline is reached again near the mouth of Shield's creek, where this stream follows the anticline closely. Passing up Shield's creek to the southeast corner of section 35, 4 S., 25 W., the county line is crossed a little below the mill of Middleton Reynold's, which is in the northeast corner of section 3, 5 S., 25 W., in Pike county.

CHAPTER XI.

Pike and Howard Counties.—Northwestern Portion.

A trip was made across Pike county chiefly for the purpose of connecting the geologic structure of Montgomery county with that of the mining districts of Sevier county. A description of the route taken and a brief discussion of the salient features of the rock folds already described, will be all that is required in this place.

At Middleton Reynold's mill, on the northeast corner of section 3, 5 S., 25 W., Shield's creek emerges from a deep gorge that winds through a gap between Brook's Mountain upon the east and another high ridge upon the west, The upper part of the stream runs near the axis of a fold, occasionally following the strike of the beds, but twisting about in a course that gradually carries it against the dip upon the southeastern side of the anticline. The gorge is not precipitous, except upon the western flank near the source of the creek. The dip is S., 27° E., decreasing up the stream from vertical to 75° or less. A narrow syncline is crossed by the stream about a mile above Reynold's mill near Wm. H. Coffman's house.

The Copper Lode.— In the southwest corner of section 2, 5 S., 25 W., the beds dip 58° N., 27° W. Mr. Coffman has dug into the bank of a stream at this point, exposing half a dozen layers of shaly rock, varying in texture from a soft, crumbling bluish earth, more or less laminated, to tough, compact black shale. Near this exposure is a patch of iron tufa intermingled with shales. The outcrops here are much like those described in connection with Wikel's pyrite deposit in Garland county.*

***Mr. Coffman exhibited numerous specimens of pyrite, pyrolusite, manganiferous iron ore and limonite, which he had collected from the adjacent country. This region deserves thorough exploration.**

The earthy shales are here known as "black mud." A few rods up stream the same beds, much contorted, are again exposed. About a quarter of a mile beyond the Copper lode, in the northwest quarter of section 11, 5 S., 25 W., there is another exposure of the black shale in the bed of a stream. This layer also carries a seam of the "black mud," two inches in thickness.

Entering section 10, and crossing to section 9, thence to Georgia on section 16, and on through sections 17 and 18, 5 S., 25 W., the road passes over soft red and white sands, apparently of tertiary or post-tertiary age, with occasional exposures of hard rock. The dip, wherever observed over this area, is from 70° to vertical, N., 27° W., changing to 70° S., 27° E., in section 17 or 18. From section 18, 5 S., 25 W., to section 8, 6 S., 26 W., where the Clear fork of the Little Missouri river was crossed, the road is very sandy, and only occasional hard, sandy and novaculite beds are visible. Enormous neozoic deposits cover the whole of the wide valley of the Clear fork in this region; and the underlying structure is largely obscured, except where the present streams have uncovered the earlier beds. On the north bank of Rock creek, on section 9 (?), 6 S., 26 W., there is a good exposure of the brown and red sands of the millstone grits. Going westward one then passes over bands of gritty rocks, followed by soft shales, with intercalated ferruginous layers. The hard shales are exposed on the Little Missouri river at Star of the West, where the outcrop forms a natural dam, which has been utilized as the foundation of a mill-dam. These tough, black layers dip 65°, S., 27° E.

The road from Star of the West to New Hope passes along a water divide over the same kind of country as that described in the preceding paragraph. No exposures occur, except at short distances off the road in ravines, where the gray grits may occasionally be seen in juxtaposition with the underlying shales. The sandy deposits continue along the New Hope and Locksburgh road beyond the line between Pike and Howard counties. The route followed was through sections 16, 20, 30 and 31, 6 S., 27 W.

THE RELATIONS OF FOLDS OBSERVED IN PIKE COUNTY.

The dips on Shield's creek, in 5 S., 25 W., seem to imply the existence of two anticlines separated by a narrow syncline. These probably represent what have elsewhere been recognized respectively, as the Golden Wonder anticline, the Clear Creek syncline and the Gray Eagle anticline.. The route pursued through Pike county was nearly in the line of these folds.

From observations made in Howard and Sevier counties, it would seem that New Hope is near the axis of the Clear creek syncline, but the superficial deposits wholly obscure the structure at that point.*

From the west line of Pike county, southwestward as far as the crossing of Holly creek, in Howard county, near Reese Henry's house, in section 9 (?), 7 S., 28 W., the sands and clays are, practically, the only formations exposed. The divide between the Muddy fork of the Little Missouri and branches of Holly creek, probably in section 11, shows fragmental deposits made up of members of the grit series, and uncertain outcrops of the black shales appear at rare intervals. West of the crossing of Holly creek, the shales are exposed in the low terrace on which Mr. Henry's farm buildings stand. All dips observed are S., 27° E., gradually increasing northwestward from 70° to more than 85°. The whole of the route from near the northern boundary of Pike county to the watershed west of Holly creek, lies along the course of the Clear creek anticline. The ancient drainage over the wide area east of this line, which is now covered by later deposits, is very much obscured; but there is evidence of the existence of an irregular cretaceous shore line south of the district, and probably the thick detrital accumulations of the tertiary have been largely derived from the neozoic rocks.† A fair section of a portion of the colored clays and sands is afforded by the exposures along the valley of the Muddy fork. The upper part of Holly creek appears to have been at one time a tributary of the Little Missouri, but its course has been deflected by the shales in 7 S., 28 W., and it has been made a part of the Saline river drainage. The post-tertiary deposits continue westward to the Indian Territory line and beyond, but they do not wholly obscure the axis of the uplift.

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*In the Mineral Resources of the United States for 1883, p. 672, it is stated that "stibnite, with jamesonite and galena ores, in Pike county, occurs traversing sandstones." If so the exposure must be in the line of the Accident anticline, west of the route followed.

†The loose white sands observed in the southern tier of sections in 4 S., 21 and 22 W., are, in every respect, identical with the deposits here exposed.

At J. A. Dyer's, on section 8, 7 S., 28 W., the country is flat and covered by the sands and clays. In section 7 a decided change occurs in the topography, due to the appearance, at intervals, of the tough, lower grits, dipping at a high angle, N., 27° W., upon the side of the Clear creek anticline. The sands continue, even upon some of the higher ridges, but the more recent fragmental material noticeable at Dyer's, becomes gradually coarser and more abundant westward, particularly upon the lower lands bordering the streams.

The Golden Wonder axis passes through sections 12 and 13, 7 S., 29 W., though it is not very evident near the road, which has been laid out over the sands for the most part. At the crossing of Saline river, above Potts's house, on section 9, 7 S., 29 W., not far from the axis which seems to be the prolongation of the Gray Eagle anticline, the neozoic deposits have been cut through to the black shales, but the tough, gray grits appear upon the west bank. From this point across the northeastern corner of Sevier county, the road is new, following the high sandy ground with only occasional exposures of the gray grits and sandstones, which dip 60° N., 27° W. On section 35, 6 S., 30 W., in the Cossatot drainage basin, and westward, the tertiary sands and clays prevail.

THE RELATIONS OF FOLDS IN HOWARD COUNTY.

The assignment of the uplifts observed in Howard county to definite positions corresponding to the folds which were traced out northwestward, is not made without some hesitation, and yet it will be seen that the relative widths of the anticlines and synclines, the angles of dip in each particular case, and the peculiarities of structure are all markedly coincident. At least it may be claimed that any other arrangement would be far more incongruous, and it will be seen beyond in these pages, how symmetrically the system works out in Sevier county and northward, as it could not do with any other adjustment of the folds. To make this fact more apparent, it is proper to remark that, in every case, the trend of each fold has been plotted from the observed strike, and afterwards the field notes have been studied and the sections marked in which exposures were seen. This method would make the writer absolutely certain that his conclusions are correct, were it not for the possibility of inaccuracy in the maps necessarily used, and the very narrow spaces between the folds in certain cases. However, one strong corroborative fact is the appearance of the broad intervening areas always in the same relative positions.

CHAPTER XII.

Sevier County.—Northern Portion.

The mining area in Sevier is confined to the northern part of that county, and the strata, which are likely to justify exploration for any of the minerals now under consideration, are not extensively exposed beyond the southern line of township 7 S., in ranges 30, 31 and 32 west. Below this the grits assume importance only for a short distance, and further south they are covered unconformably by cretaceous beds. The Golden Wonder and Gray Eagle folds cross 7 S., 29 and 30 W., the latter running also through the southeastern corner of 7 S., 31 W. Both were crossed in the northeastern corner of Sevier county, one at the Howard county line on the Saline river and the other near the divide between the Saline and the Cossatot on sections 6 or 7, 7 S., 29 W. Neither axis is very conspicuous in this district, nor has any mining been attempted in the outcrops.* So far as could be learned, the conditions are quite similar to those observed in Montgomery county along the trend of these uplifts, excepting that the grits here cover the shales, and the surface relics of ancient hot springs are wanting, while the post-tertiary sands, gravels, and boulders obscure the structure very largely.

THE ANTIMONY MINING DISTRICT.

Within a tract not exceeding two miles in width by nine miles in length, mostly upon the Cossatot river drainage, and wholly in township 7 S., ranges 30 and 31 W., extending southwestward from Antimony City, are mines which have been worked more or less for antimony ores since 1873. In this place, only the geology of the district and a brief description of the deposits will be presented. The workings lie along two prominent parallel trends which may be readily recognized as the continuations of uplifts already defined through the counties northeastward.

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*The Busby mine on the Saline river, section 4(?), 7 S., 29 W., is probably upon the Gray Eagle belt.

The Accident Anticline.—This axis is characterized in this region by low structural ridges of the tough, dark grits, and wherever it was passed, much circumspection was necessary in order to detect it as a fold. There seems to have been no fault in connection with it, but rather a slipping of the beds upon each other. The Accident anticline appears to cross the north line of Sevier county near the northwest corner of section 2, 7 S., 30 W. Although it was not clearly distinguished on the route travelled from Saline river to Antimony City, there is the semblance of such a structure near the divide between the Saline and Cossatot basins in section 35 or 36, 6 S., 30 W., east of Hester's. This and the adjoining folds, which were traced through Montgomery county, lie too far west to be observed on the route taken through Pike county. The course of the Accident anticline through Sevier county is apparently across sections 3, 4 and 8, to near Mr. Clinton's house in section 7, 7 S., 30 W., thence into section 13, 7 S., 31 W., and thence southwestward in the direction of Ultima Thule. The road from Antimony City to the Valley mines crosses this fold at Clinton's, and re-crosses it in section 13 (?), upon the west side of the Cossatot river.

As far as is known the outcroppings of the antimonial ores lie west of the Accident axis or directly upon it. The deposits have been worked almost wholly at points where natural exposures occur, and little exploration has been attempted beyond the proving of such deposits as have been readily detected by surface indications. The geology of the eastern belt of mines, which follow the northwestern slope of the Accident anticline, is not yet clearly defined by the excavations, or, at least, by the accessible portions of the workings. The conclusion is justified, however, that some agency has been at work here, which was not so active along the same axis in Montgomery county. Still, the same process was apparently in action once

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The Stewart Lode.—In section 4, 7 S , 30 W., not far from the office of the U. S. Antimony Company, and about three-quarters of a mile south of Antimony City, is one of the most important ore outcrops in the region. It has been known since 1877, when it is said to have been discovered by Mr. J. H. Anderson.* The vein, or seam, of quartz which constitutes the gangue is apparently interstratified with the black shales which are adjacent upon both sides, and which hold a position near the upper part of the tripartite shale series. Considerable work was done upon the surface at the original location, where erosion had removed the shales upon both sides so as to leave the quartz standing like a wall above them, the dip being 60° to 80°, N., 27° W.† The road from Antimony City to Jordanbrook passes across a portion of the old workings at the southwestern end of the exposures, which have been traced along the Accident fold northeastward for about three-quarters of a mile. The U. S. Antimony Company now owns the whole outcrop and has erected a smelter.

Large masses of the ore, which is principally stibnite, or antimony sulphide, have been taken out at various times. According to Wait, "prior to 1878, one piece of apparently solid stibnite, weighing 720 pounds, was shipped to Little Rock; other pieces, even heavier, were raised to the surface. One other piece furnished 1250 pounds selected ore."

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*Professor Chas. E. Wait, late Director of the State School of Mines and Metallurgy, Rolla, Missouri, has described some of the antimony mines of this section in a valuable paper published in the Transactions of the American Institute of Mining Engineers, Vol. VIII., 1880, pp. 42-52. The facts given in the present report however are from later personal observations.

†Professor Wait (Loc. cit., p. 49) gives the strike of this and of all the other antimony deposits of the district, as N., 13° E. His own statements contradict this assertion, for he speaks of the continuation of this lode, "in an easterly direction," and in another place with the same strike, "N. 13° E.," he makes the dip N. As the real strike is N., 63° E., it may be a typographical blunder, although it occurs often.

Pure stibnite carries nearly 72 per cent. of antimony. Much of the product of this lode, when separated from associated minerals, is quite pure. A specimen collected and analysed by Professor Wait gave:

Antimony	69.87	per cent.
Sulphur	27.91	...
Iron	.02	...
Zinc	.01	...
Silica	2.69	...
	100.50	

Pure stibnite requires only 28.2 per cent. of sulphur.

Specimens collected by this Survey are equally pure. Galena is also abundant, particularly at the old May shaft at the northeastern end of the exposures. In some places the stibnite and galena are intimately mingled in minute grains, while at other points or in the same situations the two minerals may readily be distinguished and separated. Very small proportions of the sulphides of iron, zinc, copper, bismuth and cadmium occur, as shown by wet analysis and by the blowpipe. Traces of gold are rarely present, but silver is sometimes found in workable quantities in the galena and oxidized lead ores. At the western croppings, and elsewhere on the surface, this last class of minerals is rather common. Bindheimite, a hydrous lead and antimony oxide, of lemon yellow color, carrying from two to three per cent. of iron, is abundant in patches With these occur heavy lead bearing antimony sulphides, or antimonial lead sulphides, such as jamesonite and zinkenite.

The May Shafts and Cuts.—The old Stewart lode extended several hundred feet, the greater portion of which was quarried in open cut to the depth of twelve feet, and a shaft was afterwards sunk. The U. S. Antimony Company has explored the quartz bed eastward, making a number of openings. Half a mile northeast of the Stewart shaft is what is known as the old May shaft on section 3 (?), 7 S., 30 W., 60 feet in depth, now abandoned on account of water. Here some excellent ore was obtained, comprising stibnite, jamesonite and gaerosion of a different character. This is well indicated at the the forks of the Roaring fork, in section 9, 7 S., 32 W., and in section 10, near the Davis mine. In sections 9 and 10 the rocks dip S., 27° E. The change in dip and the transition from a rather flat, shale area to the precipitous cliffs of the grits, is quite sudden, showing the downthrow to be upon the northeastern side of the fault. The Blue Mountain axis was observed only in sections 9, 10, 3 and 2, 7 S., 32 W., in Sevier county, but from all that could be learned, it seems certain that it continues southwestward to the boundary line of Indian Territory at least. The Bellah mine is on or near its course. This mine was shut down and not in shape for investigation at the time of the writer's visit, and was therefore not examined.

The Davis Mine.—In section 10, 7 S., 32 W., upon a branch of the Roaring fork, some prospecting has been done directly in the Blue Mountain axis. The stream here follows very nearly the fault line, exposing the black shales upon the eastern side, and high vertical walls of the grits and sandstones upon the western side. A shaft, with a small pumping and hoisting outfit, was being worked in August, 1887, in an attempt to strike an ore pocket that had been previously struck in a tunnel less than fifty feet lower. The strike of the deposit being along the general course of the stream, some explorations up and down the narrow valley had also exposed patches of ore. Although very little work has been done and the quantity mined has not been large, the product has been of good quality. The minerals are galena, chalcopyrite, sphalerite, some tetrahedrite and allied forms. Assays of the specimens gathered here would be of but little use as guides to the value of the mines, for there is very little ore in sight. The conditions are in most respects the same as were reported at the Montezuma mine in northern Montgomery county (chapter VIII), but in Sevier county the external evidences of hot springs are absent. It is probable that this area was covered by the sea while the thermal springs were active in the unsubmerged areas northeastward along the same uplift. The Blue Mountain belt certainly deserves thorough investigation. The

Along a line bearing approximately S., 63° W., from the antimony mines, already described, the Accident axis continues beyond the limits of this report.* Many "prospect holes" have been excavated in the quartz outcrops, some of which promise well, but no extensive mine work has been done. An assay of quartz collected at these places was made by the Survey, but no gold or silver were found in it. It is a significant fact that no discovery of antimonial or other ores has been made upon the northeastern slope of the Accident anticline. The axis itself may be regarded as the eastern limit of the antimony belt. The northern boundary, as now developed is the line between Howard and Sevier counties, in range 30 W., but this will probably have to be extended very materially when explorations have been completed. The southeastern corner of the available belt in the State of Arkansas is not far from Ultima Thule.

THE BROKEN ROCK AXIS.

West of Antimony City the country is extremely rugged for a little distance. This tract is remarkably similar in its geologic aspects to the area traversed by the Broken Rock anticline in the northeastern portion of Montgomery county, and the topography of the two districts is not less alike than would be expected from the differences in the intensity of the ancient erosion. The line of the fold and fault, as nearly as can be here reported, leaves Howard county less than a mile west of Antimony City, and passes southwestward across Sevier county, by way of the northwest corner of section 5, to the southwest quarter of section 6, 7 S., 30 W. Entering 7 S., 31 W., it continues apparently through the southeast quarter of section 1, across sections 12, 11, 10, 15, 16, 17, 20 and 19. This course prolonged carries it across the Roaring fork in section 34, 7 S., 32 W., and takes it to the Indian Territory line in section 7 or 18, 8 S., 33 W.

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*The writer has traced the outcrop of the antimony horizon several miles beyond the points indicated, and the quartz is persistent, standing out in the topography at intervals, like a wall. Judicious prospecting in this belt from Ultima Thule northeastward to the ridges west of Caddo gap, is likely to be well rewarded.

The western edge of the antimony area follows very closely the Broken Rock axis, and the western belt of mines is chiefly confined to this axis and to the southeastern slope of the fold. All the antimony mining in Arkansas is restricted to the narrow space between the Accident and Broken Rock uplifts.

The Accident anticline ores are in the spaces left by a comparatively uniform slip-fault, but the Broken Rock fault, here as elsewhere, is much more complicated. As a consequence, the quartz bodies of the latter tract are usually very irregular in thickness and uneven in dip and quality.

The Antimony Bluff Mine.—Upon a high ridge on the east bank of the Cossatot river, on section 6, 7 S., 30 W., there are several small shafts and "prospect holes," from which ore similar to that of the May shaft has been taken. The strata, which are tough greywacke, or fine grained grits, with the ore in a quartz gangue, dip 79°, N. 27° W.*

This mine was discovered in 1874, and in 1876 it was worked for a time with some success, but when water became troublesome and the ore ran out in the shaft at the depth of 60 feet, exploration was discontinued.

In the lower workings of this mine, nearly pure stibnite was extracted. Prof. Wait found in one sample less than three-tenths of one per cent. of foreign substances, of which 0.229 per cent. was gangue, 0.055 per cent. copper pyrites, and 0.005 per cent. bismuth sulphide.†

Another sample with less than one per cent. of impurities, yielded:

Copper	.05 per cent.
Bismuth	.11 " "
Iron	.24 " "
Silica	.50 " "
Silver	trace.
Arsenic	minute trace.

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*Prof. Wait, (loc. cit., p. 45) makes the impossible combination of "strike N. 13° E., with a dip of 70°, N." for the vein, which he reports as passing through the rock strata.

†C. E. Wait, loc. cit., p. 48.

Other analyses by Prof. Dunnington of the University of Virginia, and by Prof. Mallet of the same institution gave similar returns.*

On the north side of the shaft a streak of several inches, carrying lead up to nearly 40 per cent., and some iron and zinc, is rather persistent. A few ounces of silver have been reported in specimens of this quality of ore. Jamesonite and zinkenite, more or less altered by partial replacement of the lead by iron and zinc, are the prominent minerals besides stibnite. The surface portion, however, to the depth of twenty-five feet, yields a considerable proportion of ochreous antimony ore, chiefly cervantite. This is a product of oxidation and gradually runs into the sulphide, stibnite, below.

The Bob Wolf Mine.†—This mine on section 10, 7 S., 31 W., was not visited by the writer.

The Valley Mines.—The U. S. Antimony Company has made considerable development upon two properties in the valley of a stream flowing westward into a branch of the Roaring fork of Little river. These are in section 20, 7 S., 31 W. The Valley mine is farther eastward than the Otto mine, and it has less development. The workings, August 15, 1887, consisted of a shaft 82 feet in depth, with three drifts running off north and south, about 25 feet apart. Level No. 1 ran north 28 feet, and south 17½ feet. Levels Nos. 2 and 3 were not extended southward from the shaft, but ran north 33 feet and 16 feet, respectively. The country rocks dip from 70° to 80°, S. 27° E. There are traces of a vein structure, or of a bed of ore, in level No. 1 in both directions from the shaft. The existence of feeders or strings of ore in crevices indicate that some better ore-body may occur in the neighborhood. It is stated that some good ore has been taken from pockets in the mine. Judging from reports and the thin seams observed, the product is not materially different in quality

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***Dunnington, Proc. Amer. Association Adv. Science, Nashville meeting, 1877; J. W. Mallett, Chemical News, No. 533.**

†See Trans. Amer. Institute Mining Engineers, Vol. III., 1874, p. 150, in which Arkansas antimony ores are discussed.

from that of the Otto mine. A good pumping and hoisting plant of simple type is connected with the shaft, and the development has been executed in a workmanlike manner.

The Otto Mine.—The ore taken from the Otto mine is much like that of the Antimony bluff and the Bob Wolf mines of the same axis, but lead is more commonly present. A sample composed of a general average of the unassorted ore from different parts of the mine was partially analysed by the Survey, with the following results:

Antimony	9.19 per cent.	(Fire assay.)
Lead	15.81 per cent.	(Cyanide method.)

This ore was highly siliceous, but the method of assay for antimony is, as the assayer remarks, "only calculated to show the yield by smelting processes."

No. 1063, an example of stibnite from the large ore-body at the breast of the fourth level east, forty-one feet from the shaft, was not assayed separately, but it is undoubtedly much richer in antimony and less rich in lead than the preceding, for when mixed with it the combined sample yielded:

Antimony	21.54 per cent.
Lead	9.46 per cent.
Silver	1.2 ounces per ton.
Gold	trace.
Copper	none.
Manganese	none.

These results must not be regarded, however, as fair tests of the quality of the ores, for they can be readily assorted to yield as well as other mines on the belt. The stibnite is remarkably pure, and but little hand picking is needed to remove the quartz gangue which is raised with it.

A good sample of the "blue mud" was submitted to the Chemist of the Survey, who reported: "No. 1061 contains a considerable amount of antimony. By the wet test neither gold nor silver was found." The Otto mine has a very good plant of machinery and is opened in an excellent manner.

The Smelter of the United States Antimony Company.—The United States Antimony Company has gained control of all the antimony ores of Sevier county now being worked. There is every reason to expect numerous other important discoveries whenever the district shall be thoroughly explored, but at present this company is doing all the mining work. They are interested in the May, Stewart, Convoy, Valley and Otto mines, and were working all but the first two in August, 1887. This company has also erected a four-ton smelting plant half a mile southwest of Antimony City, and the metallurgist of the company has demonstrated the adaptability of the works to the treatment of the ores. Of this, however, there can be no doubt, as the ores are not such as require complicated processes for reduction. Specimens of regulus and of the sulphide taken from the product are of excellent quality.

The saving of the silver from these antimony ores may not become a source of revenue, and in view of the varied character of the minerals, it is quite possible that a part or the whole of the metallurgic treatment may be best done by electrolytic processes. In any case the future of the industry seems to be a very promising one.*

The Blue Mountain Fold.—In section 11, 7 S., 31 W., the northwestern slope of the Broken Rock axis may be made out by the dip of N. 27°, W. 80°, on the road from Jordanbrook to Silver Hill, a little west of the junction with the road from Antimony City to the Valley mines. From this point westward nearly to the Roaring fork, no change in the direction of the dip was detected, but it gradually diminishes in pitch to less than 60°. The hard rocks outcropping over the intervening country are chiefly the tough grits, but the post-tertiary sands cover wide tracts, affording a few good exposures of earlier strata, except in the northwestern corner of Sevier county, in 7 S., 32 W. Here the massive grits abound and the topography is very rugged, resembling very much the country northwest of Silver City, in Montgomery county, where the Blue Mountain fault passes. The same characteristic of the fault is noticeable here, but there has also been considerable erosion of a different character. This is well indicated at the the forks of the Roaring fork, in section 9, 7 S., 32 W., and in section 10, near the Davis mine. In sections 9 and 10 the rocks dip S., 27° E. The change in dip and the transition from a rather flat, shale area to the precipitous cliffs of the grits, is quite sudden, showing the downthrow to be upon the northeastern side of the fault. The Blue Mountain axis was observed only in sections 9, 10, 3 and 2, 7 S., 32 W., in Sevier county, but from all that could be learned, it seems certain that it continues southwestward to the boundary line of Indian Territory at least. The Bellah mine is on or near its course. This mine was shut down and not in shape for investigation at the time of the writer's visit, and was therefore not examined.

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*The writer's observations in Howard county were all made in August, 1887.

The Davis Mine.—In section 10, 7 S., 32 W., upon a branch of the Roaring fork, some prospecting has been done directly in the Blue Mountain axis. The stream here follows very nearly the fault line, exposing the black shales upon the eastern side, and high vertical walls of the grits and sandstones upon the western side. A shaft, with a small pumping and hoisting outfit, was being worked in August, 1887, in an attempt to strike an ore pocket that had been previously struck in a tunnel less than fifty feet lower. The strike of the deposit being along the general course of the stream, some explorations up and down the narrow valley had also exposed patches of ore. Although very little work has been done and the quantity mined has not been large, the product has been of good quality. The minerals are galena, chalcopyrite, sphalerite, some tetrahedrite and allied forms. Assays of the specimens gathered here would be of but little use as guides to the value of the mines, for there is very little ore in sight. The conditions are in most respects the same as were reported at the Montezuma mine in northern Montgomery county (chapter VIII), but in Sevier county the external evidences of hot springs are absent. It is probable that this area was covered by the sea while the thermal springs were active in the unsubmerged areas northeastward along the same uplift. The Blue Mountain belt certainly deserves thorough investigation. The

But, with all this variation, there are certain common characteristics which may aid in solving the problem of their origin, or, rather of their resistance to destructive agents. A careful survey of Polk county and of its northern boundary will show that the culmination of the pre-cretaceous disturbances was in the region beyond the northwestern end of the Trap Mountain chain, as here defined. That portion of the mountainous area, by reason of its greater resistance, and probably also because of the directive action of the hot springs fault, determined to a large extent the initial courses of the eroding streams; these, having finally outlined the drainage areas, the remaining effects could not be qualitatively changed by any mere structural conditions. This, at least, is all of the discussion that applies particularly to Polk county.

The folds and faults observed far to the northeast in Yell and Montgomery counties continue through the boundary line of the Indian Territory. Beginning at the southwestern portion of Polk county, and taking each in succession as it was crossed, I shall describe them, as far as possible, without reference to the actual order of observation in the field. In working out the structure of the mountainous area in ranges 29 W. and 30 W., one must climb the mountains and pay little attention to trails and wagon roads.

At J. H. McMinn's mill, in section 30, 5 S., 31 W., and for some distance northward, the upper portion of the east branch of Roaring fork runs through a country similar to that just described.

DISTURBANCES IN THE WESTERN PORTION OF POLK COUNTY.

Between McMinn's mill and Potter ten quartz ridges are crossed, with intervening shale valleys, and occasional higher hills of the grits. This district is all within the drainage area of the Buffalo and Mountain forks of Little river. In aspect it is not unlike the country west of Little Rock, where the same terrane is exposed, but the erosion is different here, and the disturbances of the strata are more pronounced. It is an interesting fact that there are twice as many of these quartz hills as there are folds in the strata. Six of the ridges were observed between McMinn's mill and a point two miles north of Cove, while four of them were crossed in going from there to Mountain fork drainage basin.

From the study of the mountainous district northeast of this territory, where the structure is more clearly revealed, it is apparent that three prominent folds should traverse the former belt, if they continue in the trends there observed. Two folds were made out in the district covered by the four quartz hills of the latter set. These five axes correspond well with those which successively appear north of the Blue Mountain fold in Yell county.

The Blue Mountain Fold.—The Blue Mountain axis is discernible on the water divide in section 36, 6 S., 32 W., whence it passes northeastward (N. 63° E., approximately) across township 6 S., 31 W., to the great southwest bend of the Cossatot river in Howard county, continuing up the valley of Harris creek, or parallel with it.

In Polk county the divide between the Cossatot and the east branch of the Roaring fork of Little river is a well marked ridge or mountain of grits, acting as a barrier along the western side of the "line road" for fifteen miles northward, nearly to Cove.

It would seem from the geology and topography in townships 4, 5 and 6 south, in range 31 W., taken in connection with the Cossatot drainage in Sevier county and the Saline valley in Howard county, that an arm of the old tertiary or post-tertiary sea extended up to the high ridges south of Dallas, which form the continuation of the ancient shore line represented eastward by the Trap Mountains, and the range south of Black Spring. The prevailing rocks east of the western shore line, where they are not covered by sands and clays, are chiefly the soft, red, yellow and white sandstones of the grit series. They dip 60° to 80° N., 27° W., decreasing in pitch as one goes northward and westward. The road curves to avoid the advancing shore line in township 6 S., 31 W., through sections 30, 29, 20, 17, 18 and 7, to Baker Post-office in section 6, where the Roaring fork drainage has cut a gap through the ridge in the softer rocks.

The Big Fork Anticline.—One might readily travel across the country between Silver Hill and Cove without obtaining any direct evidence of the folding of the strata. An axis which passes near McMinn's mill, exposes the black shales, but meagerly and that only in the creek bottom, and in a cut through the detrital deposits. The situation is somewhat like that in the course of the Muddy fork of the Ouachita in north Montgomery county. The prolongation of the trend of the axis to that district makes it appear as the continuation of the Big fork anticline already noticed. Its importance here is more insignificant than its outcrop there, for it is hardly noticeable in this part of Polk county. If it were overlooked, how ever, a very erroneous estimate of the thickness of the sandstones and friable grits would necessarily be made. Big Fork Post-office, on sections 23 and 24, 3 S., 28 W., is very close to this axis.

The Silver World Mine.—In the southwest quarter of section 14, 3 S., 29 W., a ridge of the tough grits, enclosing black shales represents the northwestern slope of the Big Fork anticline. The topography is very similar to that observed near J. C. Smith's on section 12, 1 N., 23 W., in Yell county, where a high ridge of the grits with intercalated shales rises southeast of the Crystal Hill axis, indicating a fault. There is much here also to remind a geologist of the peculiar situation below the water divide at Hatton gap on the same axis; and there is as much reason for suspecting ore of any kind in one of these places as in the other. The rocks dip about 60°, N., 27° W. They consist of dark, tough grits, with some siliceous dolomites, interstratified with black shales, carrying occasional small seams of quartz, and irregular pockets and incrustations of pyrite and azurite, or copper carbonate.

Two tunnels have been run into the base of the bluff, one of them about 600 feet, and the other a shorter distance.

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From the study of the mountainous district northeast of this territory, where the structure is more clearly revealed, it is apparent that three prominent folds should traverse the former belt, if they continue in the trends there observed. Two folds were made out in the district covered by the four quartz hills of the latter set. These five axes correspond well with those which successively appear north of the Blue Mountain fold in Yell county.

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In Polk county the divide between the Cossatot and the east branch of the Roaring fork of Little river is a well marked ridge or mountain of grits, acting as a barrier along the western side of the "line road" for fifteen miles northward, nearly to Cove.

It would seem from the geology and topography in townships 4, 5 and 6 south, in range 31 W., taken in connection with the Cossatot drainage in Sevier county and the Saline valley in Howard county, that an arm of the old tertiary or post-tertiary sea extended up to the high ridges south of Dallas, which form the continuation of the ancient shore line represented eastward by the Trap Mountains, and the range south of Black Spring. The prevailing rocks east of the western shore line, where they are not covered by sands and clays, are chiefly the soft, red, yellow and white sandstones of the grit series. They dip 60° to 80° N., 27° W., decreasing in pitch as one goes northward and westward. The road curves to avoid the advancing shore line in township 6 S., 31 W., through sections 30, 29, 20, 17, 18 and 7, to Baker Post-office in section 6, it has been supposed that this earth is a valuable product. A large amount of this soft black shale is piled upon the dump awaiting treatment. The nearest compeers of this mine, in the character of the beds exposed, aside from others in this same district yet to be described, are the Ozark and the Accident mines in northern Montgomery county. A review of the geology of the country west of the Silver World will make quite clear the reasons for this similarity in widely separated districts not upon the same axis of uplift.*

The following examples were taken from the dump of this mine, Mr. Young giving the position which is set opposite each:

No. of sample.	DESCRIPTION.	DISTANCE FROM MOUTH OF TUNNEL.	COMPOSITION.
1109	Iron ore	550 feet	Chiefly iron; no gold or silver.
1110	Quartz with film of copper carbonate. The best copper ore	250	Silver, none. Gold, trace. Copper (by electrolysis), trace.
1111	Manganiferous iron ore	300 feet, drift west	Chiefly iron. No gold or silver. Manganese, considerable.
1112	Earthy iron ore	250 feet, drift west	Iron, chiefly. Copper, trace. Calcium and magnesium, small quantity.
1114	Earthy iron ore	22 feet, 6 feet pocket	Iron, chiefly. Copper, small quantity. Tin, very small quantity. Gold, trace.
1115	Grits, etc., forming main mass of the product	Principal part of tunnel	Gold, none. Silver, none. Traces of nickel and cobalt.
1116	Pyritous black shale	18 feet and beyond.	Gold, trace. Silver, none.

Although these results are not very satisfactory, it would seem desirable that thorough prospecting of this region should be made under the advice of a competent mining engineer. Exploration is as important a branch of mining as exploitation.

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* Mr. James J. Ward has specimens of a tough rock similar to the grits of the Silver World mine. This contains crystals of chalcopyrite, galena and sphalerite. He states that it was discovered in place in section 28, 4 S., 31 W. If so, it is undoubtedly in a position similar to the one just described, viz: near the axis of the Crystal Hill disturbance, but upon the northwestern slope of the Big fork anticline.

THE CRYSTAL HILL AXIS.

The southwestward extension of the Crystal Hill anticline, observed in Yell and Montgomery counties, is probably represented by exposures near Hatton gap, where the black shales appear at the base of the grit series. No other explanation of these outcrops seems tenable. The change of dip is not pronounced, but this rather confirms the reference than otherwise, for at no point along this axis was there observed any marked degree of folding. The structure at the gap cannot all be explained by reference to erosion, and the evidences of a fault, merely suggested by the Montgomery county appearance are both here and at the Silver World mine, much clearer.

With the exceptions here noted, the rocks all appear to dip from 55° to 80° N., 27° W. The "line road" runs obliquely across the folds, thus giving the impression that the sandstones have a much greater thickness than they really have. The streams mostly run in deeply cut channels across the line of the road. It is therefore very hilly, but it traverses much territory without giving a great variety of outcrop. The tertiary sands are widely distributed, and in places very thick. Excessive erosion prior to their deposition is indicated by the irregular contours of the underlying rocks wherever they are visible.

Hatton Gap.—Post-tertiary sands obscure the structure even in the narrow canyon below the divide at Hatton gap. The road follows the ridge between the Cossatot drainage and the westward flowing branches of Buffalo creek. The Crystal Hill anticline undoubtedly was the original cause of the watershed, but erosion and post-tertiary deposits have greatly modified the topography. The Cossatot sources, representing nearly the area of the old tertiary estuary, extend up nearly to Cove in section 12, 4 S., 32 W., and much farther northeastward from the "line road." In the gap, and for some distance northward, the black shales, interstratified with grits, are exposed, all of which dip northward, N., 27° W., 60° to 80°, after the Crystal Hill anticline is crossed.

The Towry Lode.—S. M. Towry has uncovered a deposit of pyrite in the southeast quarter of section 2, 5 S., 32 W. This is near the Crystal Hill axis in Hatton gap. The mineral occurs in black shale in a situation very similar to that of the pyrite veins near Hot Springs.* There is a large quantity of the material at the surface, but it has not been developed, except by a shallow trench. Assays by Mr. Curtis Alexander, of Antimony City, Ark., of the ore selected by Mr. Towry, and tests of similar samples made by the Survey, show the absence of gold and silver, in paying quantities, and there is no geologic reason for suspecting their existence here. Should the time come when an industry based upon iron pyrites may be needed in this region, it is probable that a sufficient supply would be available to meet moderate demands. The results of tests appear in Table 1, Nos. 154, 155 and 156.

Another examination of the Crystal Hill anticline was made near the northeast corner of section 15, 3 S., 29 W., on the road from the Silver World mine to Silver Centre.†

The characteristics of the axis are there much the same as in other places, the black shales being exposed in gorges walled in by high and steep mountains of hard grits and softer included beds. The bluffs, or hog backs, upon the southwestern slope resemble those which form equivalent barriers at Hatton gap and in the southeastern corner of Yell county. Some of the beds in the mountains are probably higher in the geologic series than any yet noticed in this report.

Ward's Manganese Mines.—In the southeast quarter of section 28, 3 S., 30 W., Mr. James J. Ward, in charge of properties worked by persons interested in the U. S. Antimony Co., has run a tunnel sixty feet into a steep bluff on the northern face of Sugar Tree Mountain, at the edge of Brushy creek, a fork of the Cossatot river, near its source. The ridge is largely novaculite at the surface, and flakes of this material are scattered over the northern slope. Towards the top of the

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*Wikel's pyrite deposit, and the outcrops in the suburbs of the city of Hot Springs are described on p. 50 and p. 63.

†This is the old store and post-office of Board Camp.

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By blasting, a similar deposit has been exposed in the same ridge farther down Brushy creek at the water's edge. From its position, it appears to be a continuation of the same ore-body, and other discoveries are reported in situations apparently in the same course. The widening of the deposit in the shaft may be due to an oblique section made by the excavations, but the ore streak has much of the vein character, although it lies in the bed plane between two tough layers of siliceous rock. The second locality referred to is not in all respects like the shaft exposure in quality, but there are thin seams or veins of quartz and pyrolusite.

The geologic relations at this locality are very much like those at the Silver World mine, but the enclosing walls of the ore streak are higher in the series than those, and the novaculite beds are also wanting in that region. Moreover, the Silver World is upon the northeastern slope of the Big Fork anticline, while this outcrop is thus disposed with respect to the Crystal Hill axis.

The Graham Creek Uplift.—The disturbance apparent in Yell county at the source of Graham creek and southwestward, is probably a continuation of the anticline that traverses Polk county in the same trend, passing east and south of the town of Cove. Its course northeastward is marked by bluffs of grits upon both sides. In western Polk county, this character is somewhat modified by the great development of novaculite ridges south of Dallas; but the peculiar valley of the cove, upon the south fork of Buffalo creek, is very much like the great trough between this axis and the Muddy Mountain uplift in Yell county. In so far as structural features are concerned, excluding special effects of local erosion, the geologist, unacquainted with all the details, would readily place the two regions in the same category. Going into the cove from the

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of ore was also given the writer at the Silver Wonder mine, said to have come from the Hazel Branch lode, in the southeast quarter of section 9, 3 S., 29 W. I passed not far from this point, and observed indications of ore in a situation like that at Ward's mine. Of this the chemist reports: "No. 1119. Chiefly iron; trace of manganese. No gold or silver."

south, or leaving it northward, one meets conditions similar to those encountered in the Graham creek cove country; the sandy tracts observed there are even more striking in Polk county, and the principal differences have been caused by unequal erosion and the consequent diversity in drainage. In the extreme western portion of Polk county, this parallel cannot so well be applied from a purely topographic standpoint, and yet this area is much like the tract south and east of Muddy Mountain in ranges 23 and 24, the portion of the axis exposed in range 30 W., being more nearly the equivalent of the surface as it is in the east half of range 23 and the west half of range 22. The erosion over the whole of Polk county has, however, been much greater than in that small portion of Yell county which has been thus far reviewed.

The Graham creek axis is nowhere a very prominent feature, the fold being a low one, but it has probably undergone some crushing or crowding of the strata, which are more or less bungled in places. This is noticeable in the northwest quarter of section 28, 3 S., 30 W., a short distance above the mouth of Smoke Rock creek.*

An exposure of this fold occurs in section 8, 3 S., 29 W. No mines have been opened, so far as is known, directly upon the axis of the uplift. The rocks outcropping wherever the anticline has been observed, are among the lower grits, but usually above the horizon of the lowest member of that series.

The Irons's Creek Fold.—A little south of Cove on the "line road," trending northeastward across section 20, 3 S., 20 W., and passing south and east of Silver Centre there is another axis, which has been recognized in both mountain and valley, according as the eroding agents have reached the tough grits or the soft sandstones. Near Cove, this uplift has been eroded so as to present much the aspect of the country in section 7,

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*It is currently reported by the inhabitants that a "blow-out" or explosion, took place at this point in 1872, and a black coating of manganese compounds, which is particularly abundant upon the rocks, is said to have resulted therefrom. The incrustation is not confined to this spot, and is especially abundant at the head o Smoke Rock creek and along its banks.

2 N., 22 W., but in section 20, 3 S., 30 W., Church Mountain rises majestically as a perfect anticline of the grits among the adjoining monoclines. A magnificent geologic section is exposed in the mountains here, nearly all of which can be taken in at a glance from a position in Minn Pass, section 20, on the lofty divide, which sheds water to the sources of the Mountain fork, the Cossatot and the Ouachita. Here is the first, but not the only key to the wonderful topography of the Trap Mountains. This culmination in Church Mountain is the one relic of geologic structure, which has withstood, like a mighty giant, all the ravages of time. It tells a story to the geologist, which is nowhere else so well revealed, and which is apparent at only two other points in Arkansas. One of these is in the Irons's Creek Mountains on the same axis of uplift in Yell county, the other is the extreme culmination almost at the intersection of the base line with the Indian Territory boundary line, in the adjoining corners of Polk and Scott counties. But it is not probable that there is anywhere in the State another remnant of geologic history so complete as the section exposed in township 3 S., 30 W., between the Cossatot Mountain in section 8, and the Sugar Tree Mountain in section 28.

The exposure of the axis in section 33, 2 S., 29 W., on the road from Silver Centre to the Silver World mine, is in black shales. The anticline is plainly visible, though denuded, and there is no indication of a fault or slip. Another outcrop in section 7, near Harrison's old mill on Broad Camp creek, section 7, 3 S., 29 W., exposes grits. No mining has been reported along this axis, and it is a fact of much significance that dislocations can be detected wherever any important mineral deposits occur in Arkansas, or, at least, near enough to them to suggest mutual relations.

The influence of this fold in moulding the topography of the whole district from Cove to the intersection of the line of the Hot Springs fault in Yell county is very apparent. Any good map of Arkansas will exhibit this at a glance. Forming the great central divide of the Trap Mountains in range 30 W., it crosses the basin of the upper Ouachita river in such a south, or leaving it northward, one meets conditions similar to those encountered in the Graham creek cove country; the sandy tracts observed there are even more striking in Polk county, and the principal differences have been caused by unequal erosion and the consequent diversity in drainage. In the extreme western portion of Polk county, this parallel cannot so well be applied from a purely topographic standpoint, and yet this area is much like the tract south and east of Muddy Mountain in ranges 23 and 24, the portion of the axis exposed in range 30 W., being more nearly the equivalent of the surface as it is in the east half of range 23 and the west half of range 22. The erosion over the whole of Polk county has, however, been much greater than in that small portion of Yell county which has been thus far reviewed.

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*It is currently reported by the inhabitants that a "blow-out" or explosion, took place at this point in 1872, and a black coating of manganese compounds, which is particularly abundant upon the rocks, is said to have resulted therefrom. The incrustation is not confined to this spot, and is especially abundant at the head o Smoke Rock creek and along its banks.

In section 2, erosion has left only low hills, and the topography in range 29 has become reduced to a rolling country in which the black shales predominate.

The Canon Fisher Lode.—A claim has been located in section 24, 3 S., 31 W., at the head of the west branch of Brushy fork of the Cossatot under the above title. The rocks are near the axis, upon the northeast slope of the anticline, and in a nearly vertical position. The Chemist of the Survey has tested samples selected by the owners. The report is: 'No gold or silver; chiefly iron." This property is west of the trail through Minn Pass leading down to Ward's manganese mines, in the valley between Church Mountain and Sugar Tree Mountain. Boar Tusk Mountain is a spur running southward from Church Mountain, and forming the divide between the West branch and Smoke Rock creek.

The Worthington Mines.—In a series of low mountains at the sources of Carder's creek in sections 8, 9 and 10, 3 S., 30 W., and just across the divide at the head of a branch of Board Camp creek in section 11, a number of shafts and tunnels have been opened and two town sites located. On the town site of Golden, in section 9, the valley expands somewhat, but the streams above this point run through canyons. Most of them have cut down into the shales.

Carder's creek, flowing to the south branch of Mountain Fork, through sections 9 and 8, is upon the northwestern slope of the Muddy Mountain uplift, the rocks there dipping 60,° N., 27° W., rise rapidly to vertical in the axial line, which passes near the centre of section 9. The divide between a westward flowing branch and a source of Board Camp creek, in section 10, is also near the axis.

The Argentiferous Lode.—About a quarter of a mile east of the upper town site, known as Worthington's camp, a claim has been worked by a shaft and by cuts in the course of the stream. The shaft (twenty-five feet, August 19, 1887,) is directly on the axis of the anticline, in black shale, and a kind of crumpled, foliated, soft schist, not very different from the harder shales, except that it seems to be charged with thin way as to indicate its power to turn that stream into its own course upon both sides, by offering a resistance greater than any other fold, save one, in Polk or Montgomery county. This effect has been largely due to the great height of the original fold, but much more to the absence of faulting. The dislocations in other folds may have had quite as much to do with inducing the drainage to follow particular courses, but this very influence has left them a prey to greater denudation, owing to the weaknesses thereby exposed.

THE MUDDY MOUNTAIN ANTICLINE.

A mile and a half north of Cove, on section 1 (?), 4 S., 32 W., a quartz ridge forms an outlier to an exposure of shales in the axis of another fold, which occupies the relative position of the Muddy Mountain axis in Yell county. The same uplift, with exposures not widely different, was observed in sections 17, 8, 9 and 2, 3 S., 30 W., and in section 32, 2 S., 29 W., near the first crossing of Board Camp creek, on the road from Dallas to Silver Centre. In all these cases, there is more or less evidence of dislocation or of the sliding of the strata upon bed planes. The quartz beds have the appearance of intrusions, and in the course of the fold in range 30, the development of novaculite is extensive in places, while the remnants of hot springs are abundant. The special features of the geologic structure of this axis in the Mountain fork drainage, are the deep anticlinal valleys exposing the shales between the steep walls of opposed monoclines which rise hundreds of feet above the streams. In section 9, 3 S., 80 W., and, generally in the Rattlesnake Mountains, this characteristic is noticeable, but less so, on account of the greater denudation of the monoclinal barriers and their frequent crosscutting by the streams that flow northward to the Ouachita. Good sections of the grits are obtainable here, showing the whole series from the basal black shales, up through the tough, gray grits, overlain by the dark grits ("Accident ore,") and the dolomites, although the latter and their associates are not abundant in the hydrographic basin of the Ouachita.

In section 2, erosion has left only low hills, and the topography in range 29 has become reduced to a rolling country in which the black shales predominate.

The Canon Fisher Lode.—A claim has been located in section 24, 3 S., 31 W., at the head of the west branch of Brushy fork of the Cossatot under the above title. The rocks are near the axis, upon the northeast slope of the anticline, and in a nearly vertical position. The Chemist of the Survey has tested samples selected by the owners. The report is: 'No gold or silver; chiefly iron." This property is west of the trail through Minn Pass leading down to Ward's manganese mines, in the valley between Church Mountain and Sugar Tree Mountain. Boar Tusk Mountain is a spur running southward from Church Mountain, and forming the divide between the West branch and Smoke Rock creek.

The Worthington Mines.—In a series of low mountains at the sources of Carder's creek in sections 8, 9 and 10, 3 S., 30 W., and just across the divide at the head of a branch of Board Camp creek in section 11, a number of shafts and tunnels have been opened and two town sites located. On the town site of Golden, in section 9, the valley expands somewhat, but the streams above this point run through canyons. Most of them have cut down into the shales.

Carder's creek, flowing to the south branch of Mountain Fork, through sections 9 and 8, is upon the northwestern slope of the Muddy Mountain uplift, the rocks there dipping 60,° N., 27° W., rise rapidly to vertical in the axial line, which passes near the centre of section 9. The divide between a westward flowing branch and a source of Board Camp creek, in section 10, is also near the axis.

The Argentiferous Lode.—About a quarter of a mile east of the upper town site, known as Worthington's camp, a claim has been worked by a shaft and by cuts in the course of the stream. The shaft (twenty-five feet, August 19, 1887,) is directly on the axis of the anticline, in black shale, and a kind of crumpled, foliated, soft schist, not very different from the harder shales, except that it seems to be charged with thin

Hot Springs. Considerable oxidation has left limonite outcrops, which has given the name of Carbonate Mountain to the ridge in which this occurs. The chemist's qualitative analysis of the ore is:

No. 1106. } Specimens chiefly iron pyrites.
No. 1107. } Found:
Iron, chiefly;
A trace of zinc, and a little manganese.

The Erie Lode.—This is on section 8, and is opened by a 40-foot tunnel. It is similar in geologic position to the preceding claims.

The existence of certain minerals through this region has been proven, and we know much of the occurrence of conditions favorable to their deposition, but the question of quantity is a serious one. What has thus far been accomplished is only the determination of the best situations for mineral deposition. The real economic issue is whether the amount in the aggregate may be enough to build up a profitable industry, and whether the supply at any given point is sufficient to remunerate the miner. That subject will be discussed in another chapter.

The area over which the most satisfactory results may be anticipated seems to be in a line northwest of the Muddy Mountain axis, where the dip is about 60°, N. 27° W., following closely the following course, viz: In township 4 S., 32 W., sections 7, 8, 4 and 3 in the northwest corner; in township 3 S., 32 W., sections 35, 36, and southeast corner of section 25; in 3 S., 31 W., sections 30, 29 and 20 (the southeast corner), 21, 22 (northwest corner), 15, 14, 13 (northwest corner), and the southeast quarter of section 12; in 3 S., 30 W., sections 7, 8 and 4; in 2 S., 30, sections 34, 35, 36 (northwest quarter), and section 25, and so on northeastward. In some of these sections we may confidently look for future discoveries, of local extent at least. In places where this line crosses high mountains of the grits, however, the conditions are unfavorable. The ore crevices should be sought in the valleys or on the slopes of mountains, where erosion has exposed the edges of the strata, exact counterpart of the peculiar S-shaped twist in the quartzite, which was noticed at Caddo gap, and the rock here is much like the "Golden Wonder" quartzite there observed. The trends of the fold there and here are closely parallel, thus precluding any possibility of direct connection between them. There is little doubt but that the same agent has been in operation in both districts, viz: thermal springs.

On the opposite side of the stream the surface indications of hot spring action are preserved in the same way as the ancient relic at the Ozark mine, described on page 103. Local dips confuse the structure, and the special accumulations are of that peculiarly impalpable texture which is the result of deposition by hot springs. The surface is covered with boulders partly imbedded in a bright red earth of the same character as the material now being deposited by many of the hot springs of the Yellowstone Park. The characteristic mounds, and the structure are in every way similar to those observed in the Ozark excavations. If the "black mud," the "red mud," and the tough rock, claimed to be mineral bearing, can be put to any profitable use, there is an abundance of the material in this district, though, as far as known, there is less of it here than in Montgomery and Garland counties. Upon the west side of the creek a tunnel runs seventy-five feet, then turns north thirty feet. The extension of the deposit is apparent upon the opposite side of the ridge in another valley through which the west road passes. Carefully selected samples of the different products were taken, and they have been tested thoroughly. The following are the results;

No. 1091.—"Black mud," pasty when collected, was found to contain:

Aluminium, very much.
Iron,
Calcium, } not much.
Magnesium, slight trace.
Sulphur,
Silica, } small quantity.
Cobalt,

This, like all of the "black mud" of Arkansas, is merely a finely comminuted black shale, worked over by the hot springs, and slightly impregnated with such minerals as occur in the adjacent rocks.

No. 1092.—Black earth, hard when taken from mine. This is simply the compact drier portions of No. 1091, and yields the same ingredients upon analysis.

No. 1093.—"Red mud," or "gouge," abundant in the mine. The analysis shows it to be: "Chiefly iron; sulphur; trace of magnesium."

No. 1094.—Tough grit or quartzite, "Golden Wonder ore" like No. 1090. The chemist's test shows: "No gold, silver or lead."

The claim very commonly made regarding the "black mud," viz.: That it carries a considerable percentage of lead, will be recognized as improbable when it is known that the specific gravity of this earth is 2.4438, which is below that of ordinary shale. There is nothing in any of the above analyses to give encouragement to prospectors.

The Copper Queen Lode.—On the east branch of Carder's' creek, not far above the forks at Heiner's a curved tunnel has been cut into a cliff where there is an exposure of rock similar to the tough, jointed "Golden Wonder" altered quartz. There is not a very great thickness of this, but it is contorted in many layers, and it has about the same associations as in the Silver Queen lode, excepting that there is here a small amount of a rock stained with copper carbonate, like that described from the Silver World mine. The situation upon the northwestern slope of the fold, and not far from a fault, is identical with the Silver World structure. It must be remembered, however, that the Crystal Hill axis, on which that mine is located, does not pass within five miles of the Muddy Mountain anticline, while there are several intervening folds.

In the mine, the Golden Wonder rock makes up half of the breast, beginning at the top; below this is a more shaly material of two kinds, not specially marked, the upper layer being transitional. The material collected here was analysed separately with the following results:

No. 1095. Rock stained by azurite incrustation contains:
Gold, trace;
Silver, none;
Copper, .002 per cent. Copper ore of this grade has no market value.

No. 1096. } No. 1097. } Golder Wonder rock and the next lower layer, average samples of both together:
Gold, none;
Silver, none.

Durham's Mines.—M. E. Durham has located claims in sections 7 and 8, 3 S., 30 W., which present no new features, except insomuch as they imply that the best mineral, such as it is, may lie farther from the axis of the Muddy Mountain fold than the preceding group of mines. For lack of time, but little investigation was made of these properties, but much was learned in crossing the mountains and in working over the geology in sections 1 to 10, and 17 to 20. Mr. Durham has other workings, however, and is prospecting intelligently. He has discovered some deposits of genuine ore, although they are not yet sufficiently developed to determine their extent.

The Caledonia Lode.—This lode is in section 8, and is opened by a 20-foot shaft. The product is manganiferous iron ore, the vein being in a position not unlike that of Ward's manganese mines, already described. The following is a qualitative analysis of the ore:

No. 1103. } No. 1104. } Specimens to illustrate the best product yield:
Iron, chiefly;
Manganese, considerable;
Lead, trace. (A little galena with specimen.)
No gold or silver.

The Queen of the West Lode.—This is in section 8, 3 S., 30 W., and was opened by a tunnel seventy-five feet long, August 20, 1887. It is a pyritous deposit in a situation similar to the Towry lode, near Hatton gap and the Wikel veins near

Hot Springs. Considerable oxidation has left limonite outcrops, which has given the name of Carbonate Mountain to the ridge in which this occurs. The chemist's qualitative analysis of the ore is:

No. 1106. } Specimens chiefly iron pyrites.
No. 1107. } Found:
Iron, chiefly;
A trace of zinc, and a little manganese.

The Erie Lode.—This is on section 8, and is opened by a 40-foot tunnel. It is similar in geologic position to the preceding claims.

The existence of certain minerals through this region has been proven, and we know much of the occurrence of conditions favorable to their deposition, but the question of quantity is a serious one. What has thus far been accomplished is only the determination of the best situations for mineral deposition. The real economic issue is whether the amount in the aggregate may be enough to build up a profitable industry, and whether the supply at any given point is sufficient to remunerate the miner. That subject will be discussed in another chapter.

The area over which the most satisfactory results may be anticipated seems to be in a line northwest of the Muddy Mountain axis, where the dip is about 60°, N. 27° W., following closely the following course, viz: In township 4 S., 32 W., sections 7, 8, 4 and 3 in the northwest corner; in township 3 S., 32 W., sections 35, 36, and southeast corner of section 25; in 3 S., 31 W., sections 30, 29 and 20 (the southeast corner), 21, 22 (northwest corner), 15, 14, 13 (northwest corner), and the southeast quarter of section 12; in 3 S., 30 W., sections 7, 8 and 4; in 2 S., 30, sections 34, 35, 36 (northwest quarter), and section 25, and so on northeastward. In some of these sections we may confidently look for future discoveries, of local extent at least. In places where this line crosses high mountains of the grits, however, the conditions are unfavorable. The ore crevices should be sought in the valleys or on the slopes of mountains, where erosion has exposed the edges of the strata, or the steeply pitching sides of canyons which crosscut the beds. Where this axis passes from range 31 to 30, and in the southern portion of township 2 S., 30 W., there are vague indications of iron and manganese ores, which may, perhaps, be worth working, if properly explored. There are exposures of iron oxide along this belt on Mountain fork, south of the Cossatot Mountain, west of Durham's Pass, in positions not difficult of access.*

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*The remainder of Dr. Comstock's report upon Polk county contains a vast amount of detailed and valuable information regarding the structural geology of the northern portion of the county, but in view of the length of this report, and of the absence of mining developments through that portion of the State, it is reluctantly, but unavoidably, omitted here. It will all be available, however, in the further study of the region, and Dr. Comstock will be duly credited with the work done by him.—JOHN C. BRANNER.

CHAPTER XIV.

Scott and Logan Counties.*

On the north slope of Fourche Mountain, in 1 N., 29 W., and 28 W., a semi-concretionary bed is exposed, which is persistent over the country to the northwest. It consists of a coarsely granular sandstone, rather soft throughout, in which a dense iron cement of lenticular form has been infiltrated or segregated. Frequently the ironstone portion occurs as a cup or closed mould, which, when broken open, is found to be filled with the sandstone. Often in the fragments lying about exposures only the cement or mould remains. These have much the appearance of broken iron castings about a stove foundry, being usually rusty upon the surface. Analysis of a specimen shows the material to be an impure limonite, carrying 14.72 per cent. of iron oxide, or 10.3 per cent. of metallic iron. Better selections might be made, but it does not seem likely that this ore will become a profitable one.

Cox's Alum Springs.—On the southwest quarter of section 5, 1 N., 28 W., the water flowing from the shales is highly charged with mineral ingredients. Much of it is highly concentrated and cannot well be drunk without dilution. It is similar in taste to the well water at Sloane's on the southeast quarter of section 31, 3 S., 25 W., referred to on page 126. Mr. Cox has a number of tanks or pans in which he first soaks and boils pieces of the rock, afterward evaporating to dryness the solution obtained. Some of the reddish powder, in all respects like that made by evaporating the water of Sloane's well in Montgomery county, was analysed with the result stated on page 126. Some quarrying or digging has been done along the line of the fault which occurs at this place, and in the gorge of a stream which follows the fracture for some distance. At the head of the gorge, several natural and artificial pools collect strong alum water from crevices in the rocks.

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*Dr. Comstock has written a valuable chapter upon the structural geology of Scott county, but for reasons mentioned on the preceding page I have been obliged to omit everything except his notes upon economic geology.—JOHN C. BRANNER.

Manganese Ore.—Highly ferruginous bog manganese ore, is rather abundant in low grounds along the Fourche la Fave in 1 and 2 N., 29 W., but its source has not been clearly ascertained. It is not thick or very solid, as a rule being readily turned up by the plow. It is probable that a bed or vein of manganese ore of economic value runs across the country in this region. Solid pieces of manganiferous ore, claimed to have been taken from a deposit in section 16, 1 N., 30 W., were shown the writer.

The Belt Lode.—Upon the strength of the discovery of a supposed vein on section 18, 3 N., 31 W., several mining claims were located upon the mountain sides, in the wild country south of Cauthron. The material mined was thought to be gold bearing. The Belt lode shows a fracture in the cut with a slip of the rocks, the fault plane dipping 85°, and the line of fracture running nearly with the dip, which is here 60°, S., 27° E. This fracture has broken up the rock in the fault crevice, and the gap has been filled with "gouge" and iron tufa. "Slickensides" occurs on the east wall of the fissure, the striae dipping northward 35°. A two inch stratum of black shale appears at one side between two thick yellow layers, but in such a manner as to indicate a small vertical throw. There is nothing here to hold out any inducement to mining. Numerous similar cracks and infiltrations exist in various parts of these mountains, but they probably have little or no connection with any formations except these in which they occur.

Maxwell's Arastre.—In section 18, 4 N., 28 W., J. M. Maxwell, in the summer of 1887, had a small arastre worked by oxen. His "ore" consisted of a rock taken in section 13 or 24, 4 N., 29 W., a quarter of a mile distant. It was broken from small outcrops of thinly bedded gray and blue grits, which dip 11°, S., 27° W. There is no indication of a vein.

and no sign of any kind of mineralization. The material is a very common stratified rock, barren of gold or any other valuable ingredient. Mr. Maxwell professed entire ignorance of mining or the working of ores, yet he was devoting days of hard labor, far from home, in the attempt to save gold from an ordinary sand-rock, by means of a yoke of oxen and an arastre. His "ore" was prepared for treatment by breaking it into small pieces with an ordinary hammer. He could work from 100 to 300 pounds at a turn, each turn lasting six days.

GOLDEN CITY MINING CLAIMS.

In sections 34, 35 and 36, along the road to Golden City from the southwest, there is very little to be seen except sand, although the valley walls upon both sides are mountainous and rocky. The scene of the excitement of 1886-7 is a well situated town site in a sandy flat in section 31, 5 N., 27 W. The rock which here forms the bed of the valley is black shale, dipping S., 27° E., 12° to 15°. The following are the principal workings:

The Emily Shaft.—At the southwest edge of the town of Golden City, on section 31, a shaft had been sunk forty-five feet in the black shale. The dip is not above 15°. The shale contains some bands of pyrites, and very thin cross seams, chiefly of white calcite, penetrate the main rock rather irregularly. Nearly vertical joints, cutting the strata, have been here regarded as limits to the so-called vein, the sides of the fissures being styled "vein walls" by the workmen. The only source from which any yield of gold might be anticipated is the pyrite, but assays of this prove it to be barren. The owners of the property based their hopes upon the supposed existence of free gold. The method of working consists in blasting the shale at the bottom of the shaft, which is usually under water at the time of shooting. The wet, comminuted mass is then raised to the surface, where it is "panned" until the bulk of the shale has been removed. The operators claim to see "colors" in the washed ore, but in all the washings made in my presence and by myself, only fragments of copper percussion caps and crystals of pyrite could be detected. Assays of carefully washed samples give none of the precious metals, but a rather high percentage of copper.

The Florence Shaft.—The Emily Company worked in 1887, a shaft south of the one just described, under what was known as the "Sam Florence lease." This cuts a nodular pyritous layer at a depth of seven feet. The pyrite is in balls each weighing a few ounces. Gold was said to occur in these balls of pyrite, but assays of samples do not confirm the statement. See Table 1, No. 178.

The Golden Era.—This claim, lying east by south from the Florence shaft, has several openings as follows: *Shaft No. 1*, in common grit rock, very similar to that previously described at Maxwell's arastre, in Scott county; *Shaft No. 2*, east of *No. 1*, exposes the same rock, with twelve feet of greenish yellow, sandy shale overlying it; *Slope No. 4* has been run against the dip, crosscutting the beds, which dip 20° S., 27° E., the surface rock being soft, decomposed clay shale, overlying the grits that crop out between this and *Shaft No. 2*. There is a mass of rock enclosed between joint planes, and the clay mass has so filled the crevices, and afterward has become so impregnated with iron cement, that a novice might mistake it for a vein, which, however, it is not, in a mining sense.

The Arlington Shaft.—At the eastern end of the town, directly upon the main road, within an enclosure, is a shaft in the black shale, not differing in important particulars from the foregoing. There are nodular pyritous layers, the pieces being somewhat more globular than the others. Thin seams of quartz and calcite penetrate the shale in places, and a few crystals of these minerals are also present in pockets. There are said to be "two seams like this, which unite in depth and continue of double the width of one." As each of these seams is thinner than an ordinary knife blade, and entirely free from gold or silver, the prospect cannot be regarded as promising.

OTHER CLAIMS IN LOGAN COUNTY.

The Aleck Thornton Lode.—In the northeast quarter of section 18, 5 N., 27 W, a short slope has been run in a bed of conglomerate, dipping 29° N., 27° W. This rock is different from any observed elsewhere, except within a few miles of this point. It is a coarse fragmental rock, the sandstone boulders of which it is largely composed being firmly cemented by a ferruginous material, which gives a bright reddish appearance to the whole. It is overlain by shales intercalated with tough sandstones. There is no semblance of a vein and no claims are made that the deposit contains any valuable mineral.

The Peacock Lode.—The Anchor Mining Company had in the latter part of August, 1887, a small force at work in the northwest quarter of section 17, 5 N., 27 W. The rocks dip 26° N., 20° W., at this place, the section being much like that at the Aleck Thornton lode, but the beds are sandstones and shales, apparently lying below the conglomerate, which is absent here. There is a little more of vein structure, though not enough to attract much notice. There is a considerable quantity of a somewhat waxy material, which some persons call "horn silver," but which the analysis by the Chemist of the Survey, shows to be chiefly calcite. This occurs in thin seams between broken rock. In the bottom of the excavation there is a tufaceous iron-stone. None of this material yields by assay anything of commercial value.

PART II.

ECONOMIC GEOLOGY.

CHAPTER XV.

The Origin of Gold Bearing Ores.

The references made in succeeding chapters to the origin of workable deposits of gold, render necessary a brief statement of the theories relating to this subject.

While it is not possible to enter here into a full discussion of this interesting topic, we may undertake to outline it in such a way that those unacquainted with geology may form some idea of the natural processes by which gold is collected in the rocks.

Gold is widely distributed throughout the accessible portions of the earth's crust, but in this general distribution it occurs in such minute quantities as to be almost imperceptible, even by the delicate tests of the chemist, to say nothing of the impossibility of its profitable extraction.

Gold is found in workable quantities only where it has been concentrated by natural processes, and, in order that this concentration may take place, four things are requisite, viz:

I. There must be a suitable source of supply.

II. A proper conduit for the passage of an igneous or plastic medium must exist.

III. A depository must be provided.

IV. A process of segregation—mechanical, chemical, or physical—must ensue.

I. *Sources of Supply.*—Whatever may have been the ultimate source of the gold, its almost universal association with igneous rocks points to them for its immediate source. It seems, too, that the older intrusive rocks, rather than the newer volcanic rocks, have supplied the gold; not that the latter are poorer in the precious metals, but that the former have been for a longer time subjected to pressure and heat, and exposed to the action of waters that might act as solvents. Bischof says:* "A silicate of gold may be prepared artificially, and it appears that under certain circumstances it may be dissolved in sensible amount. The silica constituting the quartz associated with gold certainly originates from the decomposition of silicates in rocks, and it may be conjectured that the gold has the same origin, possibly existing as silicate."

The researches of Dr. Sandberger† uphold this conclusion, and go further with it. He carried on an extensive search for the vein metals in the surrounding rocks, and claims to have found them all in the crystalline rocks, and mainly in the basic silicates, such as mica, augite, and hornblende. Emmons also carried on a series of experiments,‡ which point to the same conclusion.

While the association of silica and gold is the most common one, there are others which must not be overlooked. Gold occurs in tellurides, in pyrites, and in other minerals. As shown by Sonstadt, it occurs also in sea water, to the amount of four cents to the ton (less than two-tenths of a mill per gallon.)

It will be seen that basic silicates abound in Arkansas, but the sequel shows that they are not gold bearing, unless at unexplored depths.

II. *Subterranean Channels.*—The conclusion stated in the preceding paragraph gains force from the fact that the disturbances in the strata have been such as to open numerous conduits for the transfer of any gold which might have been collected at great depths. Erosion has also been extensive enough in places to expose a very thick section, thus really affording a view of what has taken place far below the ancient surface.

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*G. Bischof, Chemical and Physical Geology, vol. III., p. 534.

†Untersuchungen ueber Erzgaenge. Wiesbaden, 1882."

‡S. F. Emmons, Geology and Mining Industry of Leadville, pp. 576, *et seq.*

In the lowest exposures, not only are the fissures and other conduits free from gold bearing veins, but their poverty is emphasized by the presence in quantity of the gangues which would most naturally retain the metal, if it had been present at the time of deposition. Quartz and pyrite, formed under the known conditions, which have commonly produced them in our field, would be sure to gather the greatest part of the gold, yet these minerals are barren also.

The universal presence of water, even in the deep seated and volcanic rocks, shows that the most massive of them are readily permeable by water. The natural channels for waters or other fluids percolating through rocks would be:—*a*, the bedding planes produced by sedimentation, or the successive outpouring of igneous rocks in layers; *b*, the contact planes produced by dikes breaking through other rocks, forming at the contact a more easy passage for water and other fluids; *c*, faults, fissures and cavities in the rocks, minute fractures in the constituent minerals, and the interstices between the minerals themselves. With such a diversity of means, and with all these chances, the gold, if it had been collected, must have appeared in some of these deposits. The avenues of escape, however, have been so abundant that an enormous supply would have been necessary to give each channel a measurable portion.

III. *The Conditions of Ore Deposition.*—Had there been an abundance of gold in the deeper seated rocks, so segregated that certain channels could have absorbed it in excessive quantity, the vast area of distribution for each conduit would have dissipated it to the point of extreme dilution, unless some specially adapted interruption to flow could have caused a local precipitation. There are various methods by which the deposition in veins or bonanzas might have taken place from solutions, or by which the action of heat might have produced auriferous masses profitable to mine.

It is essential that the passages for circulation be obstructed in some way before reaching the surface, so as to prevent rapid flow of the solutions, or that some change be induced in the character of the solutions. This may be accomplished by one of several modes, viz: *a*, by a close cap of impervious rock; *b*, by the constriction of the channel at one point and its swelling at another; *c*, by excessive frictional resistance along the passages; *d*, by the cooling of the liquid or the condensation of vapors; *e*, by chemical changes in the gold bearing solutions; or *f*, by the splitting of the current into numerous branches, as in passing through a much broken stratum or through a bed of gravel.

Over much of the region where gold has been sought in Arkansas, the tough grits have acted as an effectual cap, even in districts from which these rocks are now absent; but with this favorable condition the deposits that have been formed in the covered passages are not gold bearing. The fissures in the rocks now chiefly mined for gold are comparatively modern, and the folds were produced long after the deposition of the rocks. This last fact is very important, and suggests that any transfer of gold that may have taken place from below must have occurred very recently. The only opportunity for the accumulation of auriferous material has been since the deposition of the quartz, and this by the action of hot waters acting over such wide areas as to preclude the concentration of the solutions. There could never have been such vast depositions without extreme dilution, and in the places where gold has generally been sought, and where some has been reported, its occurrences are of this very nature. But, it might be asked, why may not one or another class of local deposits carry the gold? If such were plentiful, and if the conditions mentioned under I, were also present, undoubtedly there would be many accumulations of this character. The force of this truth was fully realized by the writer while in the field and, in consequence, a very careful and prolonged search was made for such deposits all over the so-called gold regions. Very many openings were visited, and large numbers of samples were collected for the purpose of settling this particular point, although it is a fact that these, the most probable sources of profit, have been almost entirely neglected by the miners. The results from them are all adverse, except in the case of the Silver City district and its continuations, where something like real vein structure exists.

IV. *The Processes of Accumulation.*—The concentration, precipitation, or segregation of gold in special deposits accessible to mining, is almost invariably the result of some kind of accessory action. That is to say, those ores which are now within the miner's reach have been brought into their present relations with the surface by some agency which has operated since the original deposition of the gold. The methods by which such results may be accomplished are: I, mechanical processes; II, physical action, and III, chemical reactions.

I. Among the mechanical modes of bringing ore-bodies within working range, upheaval, faulting, and erosion have been the most important. By these means deposits of mineral may become accessible which would otherwise remain buried beyond the reach of profitable mining processes. In our district, however, there have been no upheavals or dislocations that have exposed any great thickness of the strata, nor have these changes been such as to bring the lowest rocks in the geologic series within the reach of extensive erosion.

II. The physical action of heat, solution, and crystallization have been exemplified in various ways in the area under consideration. Igneous fusion has taken place and intrusive masses of plastic material have been forced into structural planes in the rocks; heated waters, and probably vapors, have circulated through and among the strata; and the loss of heat, resulting in precipitation, condensation, and crystallization has been equally manifest. The transfer of ingredients by solution and crystallization has not been lacking, and it is possible that the Silver City district, the Sevier county mineral tract, and other places where there is a basis for future silver industry, may yield a modicum of gold.

III. The chemical reactions necessary for the deposition of gold in such situations as have been described in the first part of this report have not been wholly absent, in so far as they are unaffected by the presence of gold itself. Had there been a free supply of this metal, there is no apparent reason why it should not have encountered favorable chemical conditions, for pyrites, and other minerals, that often carry gold under similar circumstances, have been abundantly deposited.

The deposition of quartz from siliceous solutions is chemically favorable also for the accumulation of gold, and this mineral has been thus produced in Arkansas in enormous quantities.

Summary.—Thus, to sum up in a few words, we arrive at the following conclusions, which, in view of the facts observed and reported, seem incontrovertible.

First, the various agencies which have been at work in Arkansas, have not had access to any important supplies of gold.

Second, the processes of deposition have often acted too rapidly to accumulate the gold in workable deposits.

Third, the auriferous deposition, if any has taken place, has been spread over such vast areas as to dilute the whole to a condition of extreme poverty.

Fourth, there have been no special accumulations, even in cases where such must have been formed, if gold had been present in the solutions from which other metallic ores have been locally deposited.

Fifth, at the time of the formation of the deposits in which gold is being sought, the structural conditions were unfavorable to its accumulation.

Sixth, the proper mechanical, physical, and chemical conditions have often been present, yet gold is absent from those situations in which all of these conditions have been most favorable to its retention.

Seventh, there is one more reason for the unfavorable opinion expressed regarding the future of the gold mining industry in Arkansas. It is the invariable absence of gold in the "float" and the sands and gravels, as well as in the large number of secondary deposits, which have resulted from the decomposition and degradation of the original accumulations. In some of these, at least, the chances should be best of all, but in none of them has gold been found in workable quantities.

INSTRUCTIONS TO PROSPECTORS.

Although there is but little reason to believe that any workable deposits of gold ore occur in Arkansas, it will be useless to attempt to convince all who are not geologists that such is the truth. It may, therefore, serve a useful purpose to offer a few suggestions concerning the means of detecting the presence, or the absence, of the metal.

1. Gold is not liable to occur in bedded deposits of any kind.

2. Black shale, earthy deposits, and the so-called muds are particularly unfavorable.

3. Quartz and quartzite, though more favorable than the rocks named in 2, are not likely to yield gold when they are not in decided veins. Novices are apt to mistake highly tilted beds for veins.

4. If, after applying the foregoing tests, you have actually struck gold, first be sure you have the rock in place; then procure a sample of a number of pounds; break this into small pieces (the less the quantity the smaller the pieces), mix thoroughly, and divide into four equal portions. Now take two of the portions diagonally opposite and mix them together, discarding the other two portions. Crush the mixed rock again and cut down, as before. If the sample be very large, coarse crushing at first and frequent cutting down, with successive grinding, will be allowable; otherwise the whole, or a large part, must be ground fine. The fine product may finally be "panned" in the manner familiar to gold miners. If you do

not understand that process well, adopt one of the following methods:

a. Wet the fine ore in a convenient receptacle, and add mercury (quicksilver) enough to make a paste. Shake and stir diligently for a long time; then carefully wash away the slime, leaving the mercury in the basin. If you cannot detect the presence of gold by the appearance of the amalgam, place the latter in an iron dish and heat carefully until the mercury has been driven off. Do not inhale the poisonous vapors If there be any gold it will remain in the dish.

b. Procure some strong nitric acid and some strong hydrochloric (muriatic) acid. Mix these in the proportion of one part of nitric to three or four parts of hydrochloric acid. Pour the mixture over the finely divided ore in a glass vessel, and heat it carefully to boiling. Filter or allow the mixture to settle until the liquid becomes clear. To the liquid in a separate vessel add a solution of ferrous sulphate (ordinary green copperas), when the gold, if present, will be precipitated.

CHAPTER XVI.

The Localities and Materials Said to Yield Gold.

For many years there has been a vague but persistent faith in the existence of gold in paying quantities in Arkansas. From time to time reported discoveries of this metal have caused much excitement in different localities. One by one the successive "finds" have proved barren when thoroughly tested. The little known portions of the mountainous country have always been regarded curiously, and the reported discoveries in those regions have received more ready credence, perhaps, because of the supposed existence there of granitic rocks. Nowhere in the State, at any period of mining activity, has so much energy been shown, or so much real faith in the value of discoveries, as in Montgomery county within the past three years. Large expenditures of money in the erection of mills, and in the opening of shafts by men claiming to be competent judges, have been regarded by many as adequate evidence of the permanency of this district as a gold mining area. There can be no question of the honesty of these opinions, supported as they have been, in not a few instances, by the investment of all their available capital on the part of those who have held them.

The only fields in which workable gold bearing rocks were supposed to exist in 1887 came within the limits of the counties included in this report.

Each locality is here discussed separately and upon its own merits.

THE BLOCHER DISTRICT.

Mrs. Bradfield's.—The first locality examined in which gold has been reported was the little patch on Mrs. Bradfield's farm in Saline county, three miles east of Blocher. The same kind of deposit occurs also at the old "Fletcher diggings," in Pulaski county. It is an impure limonite iron ore, and the samples (Nos. 11 and 12, of Table 1), yielded traces of gold by assay. "Float" quartz, taken from the country west of Rock creek in Pulaski county, also from section 23, 1 N., 14 W., gave traces of gold (Nos. 1 and 3 of Table 1). The Sand Carbonate mine, west of Blocher, was tested thoroughly, the sample taken representing both the average product and the portion selected by the miners as the "best ore."

These deposits are, practically, all of the same type. Though apparently of secondary origin, they are really interbedded. The presence of gold in such situations is dependent upon the source of the material, and there is no possibility of its occurrence in workable quantity, except under one of two conditions, viz: (1). The collection of the material of the deposit from the underlying rocks. (2). The segregation of the gold from the adjoining rocks. The first condition is precluded from the position of the beds, which are probably carboniferous, and the shales and sand-rocks, which form the environment, are wholly free from gold, except in places where pyrites is prevalent. It is probable that this mineral is the very meagre source of the trifling proportion of gold which was found at Mrs. Bradfield's. Other deposits of a similar character examined do not yield any gold by assay. If the waters that were instrumental in depositing these interbedded layers had access to the deep seated and possibly gold bearing rocks, the structure in this region does not indicate it. In such case, it would seem that the quartz beds, which are numerous and extensive, should carry the gold. But the assays show that these quartz beds also are barren. Their very abundance is sufficient reason for the extreme dilution of whatever gold solutions may have existed at the time of their formation. See also pages 37 and 38.

The Sand Carbonate Mine.—The Sand Carbonate mine represents the maximum of the forces at work during this formative period, and if gold were a noticeable product of the agency, the best results should be found here; but the returns from this locality are almost identical with the others. Had there been in an average specimen of the rock any such proportions of gold as have been reported, the owners would have realized ample returns upon their investment. See pages 40-42 for structural details, and Nos. 15, 16 and 17 in Table 1.

HOT SPRINGS AND VICINITY.

The Glenpatrick Lodes.—A number of openings in the suburbs of Hot Springs, known as the Glenpatrick lodes, yield traces of gold, the metal not being in workable quantity. Assays of the material are given in Table 1, Nos. 19 to 23.

The Glenpatrick property, in places where the mound structure occurs, which is referred to in Part 1, may have some tendency to a segregation of the gold, but nowhere has it been found in workable quantity.

Three samples from the Shippey mine, at Hot Springs, gave negative results. Since the writer's visit to this property, a mill has been constructed to work this material, but it has necessarily proven a failure. The Shippey mine is in no sense different from the outcrops for miles along West Mountain, or rather, along the strike of the beds, which is not coincident with the trend of the ridge. Other information concerning this locality is given on pages 64-66, and in Table 1. Nos. 24, 25 and 26.

Other Similar Deposits.—As will be seen in Table 1., Nos. 2, 9, 10, 13, 14, 18, 28, 30, 43, 51, 80, 87 and 98, that other collections of bedded quartz were made at various points, all these being in situations geologically similar to the samples previously noted. There are enormous quantities of this quartz, extending over thousands of square miles, and there is no reason why one opening should not be as rich as another, for they are identical in origin, in structure, and in environment. To furnish all this rock with gold in workable proportion would require an untold richness in the original rocks. It must be remembered that these quartz deposits are not veins, but beds intercalated with shales and other paleozoic strata. These beds may be traced across the whole State, and the points at which they are worked are simply tilted outcrops that have been mistaken for veins. Most of the workings in Saline and Garland counties are, as a rule, in beds of this character. Some of the men connected with these operations, and who have worked in quartz mines in the west, have fallen into the error of supposing these rocks to be valuable because the material is quartz. It is difficult to convince many who have obtained gold from similar rocks in Colorado, Nevada or California, that this is not also auriferous ; and it is not strange that any one who claims to be able to get high assays from these rocks readily gains enthusiastic followers. Mining claims have been located upon all the various members of the lower carboniferous series in Garland and Montgomery counties, and large sums of money have been contributed to work these beds.

The Trap Mountains.—In the Trap Mountains, in Garland and Hot Spring counties, there are many exposures of limonite iron ore included between quartzose layers, to which it is more or less cemented, and these limonite deposits have been extensively located as mining claims, although very little or no development has usually ensued. Samples of this class contain no gold, or at most only minute traces. These deposits do not differ in kind from those previously mentioned, except that they seem to represent the positions of more localized action.

"Black Mud," "Blue Mud," etc.—Totally different materials which have been regarded almost with veneration in the counties of Garland and Montgomery in particular, are the so-called "black mud" and "blue mud." It is exceedingly difficult to write of these materials in a satisfactory manner. It would be next to impossible to make unbiased persons believe that any people could have been so completely deceived regarding their true value. The inhabitants of the district, however, have become so thoroughly imbued with the idea of their fabulous value that it will be almost or quite impossible to convince them of their error, even when every means of demonstration shall have been exhausted. The facts, how-

ever, are very plain. No rock is more common than black carbonaceous shale. It abounds in the valleys all over the thirteen counties embraced in this reconnoissance. It is in regularly stratified beds, and constitutes a thick stage beneath the millstone grit. Its geologic relations, and the nature of its intercalated associates have been clearly explained in Part 1 of this report. Consult also page 51, foot note; pages 104–5, 107 and 121.

Pyrite Deposits.—In places, as at Wikel's pyrite claim, and in other localities near the city of Hot Springs, there are bands, beds, or veins of some special mineral, such as calcite, pyrite, etc., and there are instances, like the Kellogg mine in Pulaski county, where the shale beds enclose valuable ores in this way. Cases might also be cited in which the shale beds themselves are more or less impregnated with nodulary concretions of pyrite and other minerals. A very few of these have been opened and lightly worked. If there be any commercial value in these shales as gold producers, the pyritous portions must necessarily prove the most remunerative. Yet it is true that not one of the workings of this character has produced any gold worth mentioning, and the minerals taken from these claims yield no more than traces of gold by assay. Nos. 66, 67, 78, Table 1, are the best possible samples for determining the values of such material, and the results reported are the basis of the above statement. Many openings have been made in the black shale, where a geologist could not recommend such excavations. Even the proprietor of Wikel's pyrite deposit, in Garland county, has neglected his mineral bodies and opened pits in the beds of common black shale overlying them. Here and at other places blocks of this ordinary sedimentary rock have been carefully laid upon the dump and classed as ore, as notably at the Accident Mining Company's shaft in Montgomery county, at the Silver World mine in Polk county, and the Garland County Mining Company's workings south of Hot Springs.*

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*This statement refers to products which the owners and miners have saved as "ore," and not to the waste rock which lies upon many dumps. In the cases spe-

THE BEAR CITY DISTRICT.

Graphitic Shales.—One step further carries us to the graphite and graphitic shale, which in numerous situations have been carefully treasured as valuable gold bearing deposits. The Garland County Mining Company, in their tunnel in section 17, 4 S., 20 W., have struck some fair graphite, and a considerable thickness of graphitic shale occurs in the course of the tunnel. Not much reliance has been placed upon this as a gold mine. Its owners anticipate their reward from other metals, and we shall have occasion to notice it under the head of silver.

Black Mud, Blue Mud, etc.—Where the black graphitic shale is exposed in the beds of streams, it is often soft and friable, readily forming a kind of mud when wet. This condition of the rock, and the finely divided state in which it often occurs when worked over and deposited by the streams in quiet pools, are forms of the "black mud," "blue mud," etc., which have been most eagerly sought, especially by miners in Montgomery county. But there have been agencies in the past, which have reduced these shales to the condition of an impalpable powder, and accumulated it in special deposits. The Ozark mine described in chapter VIII, and the Silver Queen lode in Polk county, are good examples of this. They contain no gold, though certain assayers have reported them rich in it. Samples of this material from different localities are reported upon in Table I.

Quartzites.—A tough, quartzitic rock abundant in the vicinity of Bear City, and traceable for miles east and west of that place, has been selected as the prominent gold ore of the Bear City region, and although this, too, is a bedded formation of carboniferous age—a member of the grit series—which is exposed in many places over a wide range of counties from Pulaski to the Indian Territory, it has been pronounced rich in gold. A careful study of these rocks and their geology shows that they

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cially named above, common black shale or graphitic shale has formed a large part of the material saved as ore. In justice to interested parties, it should be added that Mr. Aughey and his associates have given favorable assay reports upon this class of rocks.

are the same beds as those exposed from the Arkansas river at Little Rock to the Indian Territory line, through the counties of Pulaski, Saline, Garland, Montgomery, Pike, Howard and Sevièr. The trend of the ridges and the character of the beds, with details of the mines, are given under appropriate heads in Part 1 of this report. The Silver Spray, Golden Seal, Golden Wonder, Lost Louisiana, and other properties are the prominent ones in the tough quartzites, which have attracted attention in the vicinity of Bear City, Montgomery county. Besides these, there are such openings as the Mammoth and its compeers, which resemble the quartz locations of the Trap Mountains, and the Ozark, which is like some of the Polk county workings. But the Golden Wonder and Lost Louisiana mines have been the main support of the camp, because upon them, and in connection with their working, the largest sums have been expended, although without any returns.

Evidence Regarding the Existence of Tellurium.—Although there is no indication whatever of any foreign mineral in the Golden Wonder rock, except thin seams of quartz, it was deemed advisable, on account of the statements made regarding its value, to thoroughly examine this claim concerning the presence of tellurium in the Bear City ores. This test is very readily made, and it is one which reveals very minute proportions of the metal when present. The writer has carefully examined the rock from the Golden Wonder, Lost Louisiana, Mammoth, Golden Seal, Silver Spray, Ozark, No Man's, and numerous other mines, both hard and soft ores of various qualities, all collected by himself in place, and in no instance has he obtained the faintest reaction for tellurium. In addition to these tests, samples have also been submitted to Mr. C. B. Gannaway, of Hot Springs, who has returned a negative report in every instance. Under date of November 10, 1887, in a letter to the State Geologist in reply to inquiries regarding his experience with tellurium bearing minerals in Arkansas, Mr. Gannaway further reports as follows: "I have examined minerals from twenty of the central and western counties of Arkansas, and have found none of the minerals you ask concerning, viz: sylvanite, calaverite, melanite, tetradymite, or tellurium. I have been induced to make many tests for tellurium, not by indications, but by reports of others; in no instance have I ever found a trace of tellurium in Arkansas minerals."

From Prof. Robert H. Richards and Prof. P. de P. Ricketts, to whom the Survey's samples of Golden Wonder and Lost Louisiana ores were submitted for assay, came reports that no gold, silver or tellurium were found.

Additional Evidence Regarding the Existence of Gold.—The opinion prevails in Montgomery county, and in some other districts, that the rocks exposed in those places are novel and that the geologic formations are peculiar. Except in a very limited sense these beliefs are erroneous. The structure, the succession of the strata, and the character of the rocks are all such as are widely known both in and out of Arkansas, and nowhere in the areas covered by them has gold been discovered in workable quantity. The conditions in all those portions of the State yet examined by the Survey are likewise unfavorable to the existence of gold in paying quantities. The only peculiarity in the Arkansas geology consists in the remnants of hot springs and their somewhat remarkable effects upon the texture of the rocks. Thus, in some particular localities, the deposits are more specialized, and these have often been regarded, by persons unfamiliar with mining and with such masses, as accumulations of ore.

Very few, indeed, of the people are aware of the many duplications of these deposits, which have been brought to light by an examination of the region adjoining the Bear City district. The products of the old hot springs are chiefly soft, fine-grained materials, often highly colored. In some instances, the working over of the shales has produced a powdery black earth or clay, which forms a pasty mass when wet. This is the "black mud" of Arkansas. It is not confined to the neighborhood of Bear City, nor is it peculiar to Montgomery county. Equally good examples occur in Polk, Garland, Hot

Spring, Pike, Sevier and other counties. The region that is occupied by the old hot spring relics, is, however, the area within which such deposits are to be found. The real "black mud" is merely a pulverulent form of the jet black shales; the "blue mud" is usually a similar substance resulting from the comminution of the graphite shales, or it may sometimes be more like ordinary clay; both varieties have received this name. The "red mud" in Montgomery county is commonly an ochreous deposit, usually manganiferous, filling cavities or crevices or occupying the throats of choked up passages of ancient springs. Many tests of these deposits, taken from numerous mine openings all over the area outlined above, have failed to reveal any gold in them. From their very nature, in most cases, they could not carry gold or any other heavy mineral, as their specific gravity is very low, and any agency that could have deposited them in their finely comminuted condition could not have brought gold to the same point. The ochreous mud, and a very light, flaky, purplish substance of a soft nature, which occurs in pockets in the Lost Louisiana mine, are commonly regarded as "tellurides" by many persons at Bear City. Tests by chemical analysis show clearly that the latter is the well known mineral wad, or bog manganese ore, and assays and special tests prove the absence of gold or tellurium or of any other valuable ingredient except manganese.

OTHER FIELDS SAID TO YIELD GOLD.

As far as known at present, there is, properly speaking, no gold field in Arkansas. In connection with the discussion of silver minerals beyond, it will be noticed that unimportant proportions of gold occasionally exist, but never in such amount or in such condition as to require or justify separate mechanical or metallurgical treatment prior to the production of bullion. There have been, however, numerous claims of the discovery of gold in other districts besides those already named. The facts concerning these may be briefly stated.

The Silver City Area.—Aside from the silver ores of this tract, which occasionally carry small percentages of gold, some work has been done upon rocks supposed to be highly charged with this latter metal. These are mostly of the same character as the beds which have been previously enumerated, such as quartz and quartzite, black shale, " black mud " and "blue mud," with occasional limonite deposits or hematite shales, none of which show, upon careful tests, any indication of the presence of gold.

Pike, Howard and Sevier Counties.—So far as gold is concerned, the remarks in the foregoing paragraph are fairly applicable to the region covered by Pike, Howard and Sevier counties, except that only a limited range of special deposits have been worked, outside of the antimonial ores, which carry but little gold. Attempts have been made here and there in these counties to work pyrite and other ferruginous materials, but no gold has been detected by assay in these products.

Polk County.—In Polk county, mining for gold has been chiefly confined to the mountainous district south and southeast of Dallas. This region has been examined with great care, and many samples have been thoroughly tested without discovering any gold, or but slight traces. See Table I.

The rocks attacked represent a general average of those which have been worked elsewhere in the State, including the black shales, quartzites, "mud" deposits, "accident ore," etc. In some instances there are special features which, however, do not affect the improbability of obtaining this particular metal.

Scott and Logan Counties.—In Scott county there has been comparatively little excitement concerning gold. In a few places, tough rocks have been prospected, but little dependence has been placed upon the discoveries announced. A very little work has also been done upon some of the members of the millstone grit in situations wholly foreign to the habitat of gold. The rocks at Golden City in structure, position, and composition are unlike any gold bearing rocks ever discovered. More than this, all these features are common and well understood in other regions, and they represent conditions and formations very far removed from those suitable for gold depositions. Fortunately but few were led to believe in the value of this property. Other deposits not far from Golden City have been worked because of their oddity, but they are all of a character wholly unfit for the carrying of gold. See chapter XIV.

For descriptions in detail of the various diggings examined, in which this metal was supposed to occur, the reader should consult the headings under the title "Gold" in the index at the close of this volume.

CHAPTER XVII.

What is a Paying Ore?

The question "What is a paying ore?" is so often asked, that a somewhat detailed answer is given in this place. This answer is the more necessary because so many persons suppose that an assay report, when it states values in dollars and cents, purports to give the actual market worth of the material tested. This, however, is a grave error. A certificate signed by a competent and reliable assayer pretends to express only the gross amount of the metals contained in the ore. Indeed, it is not customary among assayers in producing mining regions to state values at all, but to give the silver and gold in ounces per ton, and other metals in percentages. An assayer who reports money values in ores, unless he be quoting prices which he will pay for the same, is liable to mislead, for, as will be shown, there is a difference between market quotations and the actual contents of an ore. It is scarcely necessary to remark that a different practice may be common in assays of rich bullion, because in such a case the metal is so pure that very little treatment is needed to rid it of its dross.

First, in regard to the assay, it should be clearly impressed on the mind of every person who has anything to do with mining or with mining products, that no assay certificate can be of any use as a guide to mine values, unless it possess several indispensable qualities, viz:

First—It must positively represent a large lot of the ore, the weight being clearly stated.

Second—There must be evidence unmistakable that the ore came from the mine in question.

Third—The ore must have been collected by a competent, experienced, reliable, and disinterested person, and must represent a fair average of the mine.

Fourth—The lot must have been carefully "sampled" by grinding, mixing, and cutting down under the direction of one who thoroughly understands this process, until the assay pulp is an epitome of the whole original mass.

Fifth—The portion of pulp taken for the assay must itself accurately represent what the whole pulp represents, so that tests of two or more assay portions shall agree closely one with another.

Sixth—The assays must have been made by a person skilled in the chemistry of the process and familiar with metallurgical principles, and above all—

Seventh—The assayer must be of known integrity.

To determine whether a certificate has all these features, one should first be satisfied that the signature is that of a trustworthy assayer. If not, although the other essential qualities might all be present, the worth of the report would be vitiated completely. That point settled satisfactorily, one may turn to the beginning of the certificate for further details. If it read thus: "*This certifies that I have assayed the specimen of ore, marked ———, presented by Mr. —————*," it can have but little value as a guide to an investor or as a proof of anything of practical use, for however skillful or reliable the assayer may be, he has certified to nothing important, simply because he could not. Again, his paper may read thus: "*I certify that the pulp marked ——, said to be an average sample of a lot of 6000 lbs. of ore from ——— mine, yields, etc.*" In this case, the value is no greater, except that it may be possible to ascertain the previous history of the sample, otherwise such a certificate is useless for practical purposes. But, if the assayer certifies that he has tested what he knows to be a fair sample of a large lot of ore which has positively come from a given mine, it is only necessary to enquire how much said assayer knows beyond his furnace work in order to determine what reliance may be safely placed upon his opinion of a property. Thus it may happen that the signature and the outline report in the certificate will of themselves, answer every one of the seven requirements. This would be the case, should a trustworthy mining engineer report that he had examined a property, collected and sampled an average lot of ore and assayed it.

We are now brought to a realization of the great importance of securing the services of a reliable and experienced person, whose life training has been in this particular line of practical work. Seeing, then, the danger of a novice's wholly overlooking vital matters which can never escape the eye of a trained engineer, let us consider what the latter must ascertain before he can decide whether a given ore can be mined profitably.

It is not enough to know the simple value per ton. The cost of mining, of transportation, and of reducing the ore to the metallic condition, are all-important items, and there are many others, some of which will be discussed under appropriate headings in the special chapters devoted to the different metals. Nor have we solved all the problems when such general matters have been settled, for each particular metal may exist in diverse combinations, often in one and the same mine. This is especially the case with silver ores, and this complication leads to the necessity of employing different modes of treatment.

There is probably no feature in the mining industry which puzzles the ordinary miner so much as the assertion by metallurgists, that the market value of an ore cannot be determined by the amount of silver and gold which it contains. Two comparative illustrations will explain this. Let us suppose, for instance, that we have two gold ores in which the gangue is quartz. In one the gold is invisible to the naked eye, being exceedingly fine, but the quartz is very tough and flinty. In the other, a very brittle, friable quartz carries the gold in nuggets and coarse grains regularly distributed. Both are at the same distance from a stamp mill, which uses the ordinary plate amalgamation with inside battery plates. The average yield by assay is the same in each, say $8 per ton. The items of cost, comparatively speaking, may be set down as follows, without any attempt to approximate actual figures :

No. 1, Tough ore.	*Per ton.*
Mining	$1 75
Hauling to mill	50
Crushing	90
Loss in tailings and extra cost of saving the gold	2 40
Total	$5 55

No. 2, Brittle ore.	*Per ton.*
Mining	$1 00
Hauling to mill	50
Crushing	50
Loss in tailings	75
Total	$2 75

This shows how, in the given cases, an ore like No. 2 would be worth $2.80 more per ton than No. 1 of the same grade.

But this is not all. The wear and tear upon the machinery, the extra appliance necessary for catching the fine gold and the slowness of the work with No. 1, would so increase the depreciation and reduce the output of the mill, as to make a still greater contrast in the daily profits. In the case of No. 2, a plant of 25 tons capacity would realize $131.25 as against a profit of $61.25 in the case of No. 1, for an equivalent output, but for one day's work (as only about 15 tons of No. 1 could be crushed) the latter would yield a profit of only $36.75, or less than one-third the net receipts from No. 2 for the same length of time. In a custom mill this difference would certainly appear in the form of such extra charges levied upon No. 1, as would make it, for that purpose a non-paying ore. The illustration, though selected for an object, is by no means an improbable or unreal one.

When comparisons of silver ores are made in this way, even with those from the same mine, and of equivalent grade, but differing in quality, the discrepancies are much more apparent, for separate processes may be required for the treatment of each kind. Thus galena ores are adapted for smelting processes, but zince blende is detrimental, while arsenical and antimonial ores are in the way where silver is to be saved. A complete discussion of this subject, and of the details which every competent worker in these fields must have at his command cannot be undertaken here, for such a discussion would necessitate the writing of a full treatise upon metallurgy. One other illustration must suffice.

Take three lots of ore which when carefully averaged and assayed show as follows:

No. 1.	No. 2.	No. 3.
Iron pyrites with galena.	*Galena.*	*Galena with zinc blende.*
Silver ....20 oz.	Silver.........20 oz.	Silver ....20 oz.
Lead ....15 per cent.	Lead, 80 per ct.	Lead .... 30 per cent.
		Zinc... .... 20 per cent.

With silver at $1 per ounce, lead at 20 cents for each unit (1 per cent.), and zinc deductions as commonly applied, an ore buyer would figure about as follows upon these ores, supposing that he purchased only for smelters.*

No. 1 has a value of $20 in silver; the lead is too low to be paid for, or if, by having unusually rich lead ores on hand, he is prepared to treat it, he may add about $2.25 for this metal. Probably he will not want a pyritous ore, but he may have a special need for it. In the latter case a trifling addition may be made to the price, making, say $1 more, or $23.25 in all, as the gross value of the ore to him. But transportation charges must be met, and the cost of smelting must be added, besides a reasonable percentage for losses in smelting, and a fair margin of profit. The buyer must also include the cost to him of marketing his bullion, and charges for separating the silver from the lead bullion. Assuming an ore transportation charge of $3, treatment charges of $15 for this class of ore (low in lead), losses and after charges of $4, it will be seen that the miner could not market this grade of ore, for the buyer would have but $1.25 per ton profit, even if the ore were given to him.

No. 2 would be valued at $20 for the silver, but as it is a perfect smelting ore, the lead would be rated at, perhaps, 50 cents per unit, or (.50 x .80) $40, making $60 in all. The more lead the ore contains the more the smelters pay for each unit. Thus, usually 15 per cent. lead brings nothing, 20 per cent. will bring about $4, 30 per cent. possibly $9, 40 per cent. $16 and so on. The schedule price varies more or less with the market price of pig lead, of course. In this case, the cost of treatment may also be very much reduced, owing to the quality of the ore. Thus, we have charges as follows: Freight, as before $3, treatment $7, after charges $6, larger because of the quantity of lead handled, leaving $44 for profit and to pay the miner for his ore. For this material the miner will get nearly double the whole value of the silver, under the circumstances mentioned.

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*Every buyer has his own schedule, and the quality of the ore, or the particular kind most needed, may vary his offer. The methods of estimating are different with different works, but they all agree in principle and in general results.

No. 3 would be estimated at $20 for the silver, as before, $9 would be allowed for lead upon the assumed basis, making a gross value of $29 per ton. But commonly $1 would be deducted for each unit of zinc present, or $20 in all, leaving $9 per ton to help meet transportation, cost of treatment, and after charges, at not less than $15 to $18, to say nothing of margin for profit, etc. This ore, therefore, though twice as well provided with lead as No. 1, and containing the same amount of silver, could not be marketed where prices were as indicated above.

To apply these principles in Arkansas, a full knowledge of many local details is necessary. If those who have already erected smelters have clearly ascertained what is a paying gold or silver ore in Arkansas, they must have accurately estimated the cost of mining, transportation and smelting in the region from which they hope to draw their raw material; for the ores themselves, in order to pay for working, must meet all these charges and more, no matter by whom they are sold or bought.

To determine, therefore, the grade of ore which can be profitably mined in any locality, add together the cost of mining per ton, the total freight to the nearest available market, and the charges for treatment, then deduct this sum from the gross price offered for the metallic contents. Local custom works cannot usually treat ores in competition with the works which are established in the large trade centers. If, therefore, we allow very low freight rates, such as may come with railways plentiful, and estimate the cost of treatment at the schedule of St. Louis smelters, a very fair judgment may be reached as to the grade of ore that can be profitably mined in Arkansas. Five dollars per ton is certainly far below any freight rate that can be realized, and ores of silver with average percentages of lead and very little or no zinc, might be treated for $10 per ton. Upon this basis, adding $2.50 per ton for mining—a very low estimate—$17.50 must be deducted from the price paid before any profit will accrue. An average offer at the works in St. Louis for clean ores of this character would be, say 95 per cent. of the New York quotation for silver and 30 cents per unit for lead. Silver was quoted at 94 cents per ounce on November 10, 1888, in the New York market. Allowing $9 for the lead, the ore must carry $9.52 worth of silver (10.11 ounces) at New York prices, in each ton, in order to just pay expenses. The schedule contemplates better ores than this, and probably from 12 to 15 ounces would be required to realize costs, on this account. With galena ores carrying 70 per cent. to 80 per cent. of lead, a market could be found, even if they carried no silver, but we are now only speaking of gold and silver ores. As freights and mining costs are now high, and as local reduction works could not meet these prices, it is safe to say that no quartzose silver ore, carrying 30 per cent. or less of lead can be worked profitably unless it has at least 30 ounces of silver to the ton, and that only with railways to transport fuel to the ore, or the ore to the fuel, with mines well opened and producing largely, and with large capital invested in the works. At present the ores must be sent out to be treated, and under existing circumstances, no mines are so situated that they can ship their product and realize expenses, even on such grades as this. The cost of mining is not to be taken at the expense of digging out a pocket of soft ore, nor can profits be estimated by the earnings of small lots of rich ore. The total cost of all the excavation, hoisting, pumping, etc., must be averaged among the few tons of ore actually sold or mined, and this, not by specimen assays, but by actual results of tests made by crushing and cutting down in the most thorough manner.

CHAPTER XVIII.

On the Occurrence of Silver.

The conditions under which silver bearing minerals may occur in nature are more varied than those affecting the distribution of gold. The fact that but little gold is claimed to exist in the silver ores of Arkansas is valuable evidence that it is not abundant in other rocks in the neighborhood; for an examination of the deposits which carry silver shows that the source of the metalliferous impregnation has been such as to charge the veins more highly than could have been possible in the beds that have been erroneously regarded as gold bearing. There are deposits of argentiferous ores in the State, some of which are deserving of thorough exploration, although none of these have been, as yet, extensively developed. On the other hand, a considerable amount of mining work in a small way has been done in situations where there is no possible chance of success, while assays of questionable value have induced many to excavate in rocks which are even more certain to yield no silver than to prove barren in gold. The evidences regarding both these classes of deposits will be presented in geographical order.

PULASKI COUNTY.

The mining for silver in Pulaski county has been fitful, and, thus far, not profitable, but, as might be expected in the neighborhood of Little Rock, the explorations have been somewhat thorough. There are in the county three districts which demand separate consideration, viz: 1. The immediate environs of Little Rock; 2. The Kellogg mining area; 3. The region about the McRae mine.

Little Rock and Vicinity.—From time to time reports have come from various sources of the discovery of silver bearing ores in and around the Capital City, and the descriptions seem to agree fairly well with each other. The intrusive rock and the occasional vein-like masses, that occur in this area, lend some color of plausibility to the claims made, but no work of any consequence has been done. It is said that a vein bearing galena and other minerals in a quartz gangue was cut by the St. Louis, Iron Mountain & Southern Railway, in excavating for their road-bed near the present railway station in Little Rock, but that the exposure thus made was covered by order of the superintendent. The reason given for this was that the cost of development was placed by estimate at $10,000, a sum which was, at the time, regarded as an unwise expenditure. The indications now accessible do not warrant the belief that the deposit is liable to return any considerable investment made in working it. There is, apparently, no important vein nor any disturbance of the strata that could cause the accumulation of large deposits of such ores. At the same time, the proximity of the intrusive rocks and the tilted position of the strata are somewhat favorable conditions. Therefore, while no important outcrop is now known in this area, it is by no means certain that none will be discovered hereafter. The most discouraging feature is the absence of such occurrences in the places where the circumstances are most favorable, as in the immediate vicinity of the igneous intrusions. The rocks that might be supposed to be the nearest to any existing ore-bodies have invariably proven to be barren, so far as investigated.

The Kellogg Mining District.—To one unfamiliar with the geology of the region, the situation at the Kellogg mine would be regarded as peculiar, and even the skilled geologist might consider it a puzzle, if he were to examine it without close acquaintance with Arkansas types of geologic structure. The development has been so incomplete that no safe opinion as to the future can be expressed, and yet there is much encouragement in the past and present of the mines. The wonder is that they were ever discovered in such a locality, but now, that the surrounding conditions are understood, it is to be expected that other deposits of the kind will be brought to light, or that the continuation of the outcrops may be traced by means of the facts concerning their structure announced in chapter I of this report. The ores are remarkably pure and the cost of mining should not be great, though it will require capable superintendence to insure regular profits. The success of the mine, after the development has progressed considerably, will depend upon the quantity of ore and the engineering economies applied by the management. The zinc blende carries some silver, but as this ore, in most processes of silver extraction, is very detrimental, the method of treatment best adapted for the galena product cannot well be applied to this. This will necessitate the adoption of separate modes of saving the silver in the two classes of ore. Fortunately, their independent occurrence and the clean character of both ores make assorting almost unnecessary, so that each quality can readily be handled by itself at the minimum of expense. The coarse galena and the copper pyrites will probably yield from 30 to 60 ounces of silver, judging from the assays of material taken from the dump; and the zinc blende from the mine itself carries less than 20 ounces of silver to the ton. Besides these ores, there is an uncertain quantity of mineral which yields higher percentages of silver. Presumably such ingredients are mingled somewhat irregularly in the galena deposit, and to a less extent in the quartz bodies. The latter, if abundant, will require concentrating before reduction, unless it be found that the rich silver minerals occur chiefly in them; in this case such treatment would be inadmissible, on account of the inevitably excessive loss of silver.

The ores will best be reduced at or near the mines, the galena (and possibly the quartzose ores) by smelting, and the zinc blende by another process. The copper that may be contained in the smelting varieties might be saved separately, but it is questionable whether this would prove economical, except by first assorting. It is not unlikely that the district adjoining the Kellogg mines, over a narrow strip bearing approximately N. 63° E., by S. 63° W., through the present workings, will eventually become the seat of an important mining industry. But the question of quantity of ore is still unsettled.

The source of the silver is not apparent in the immediate surroundings of the enclosing rocks, but the proximity of the region to an igneous area and the complexity of the folds make the probabilities here rather favorable than otherwise. Much remains to be done, however, in order to prove the deposits thoroughly.

The McRae Mine.—No new features were shown by the prospecting in the McRae mining camp. The indications were not such as would induce a practical geologist to seek for ore, and a study of the surrounding country does not yield much encouragement. Still, there are topographic and other peculiarities which might have considerable weight with some miners and prospectors. The best opinion that can now be expressed is adverse to the district, though this should not preclude such inexpensive search as can be undertaken.

Other Localities. —There has been very little systematic exploration of the northwestern portion of Pulaski county. D. R. Hooper, who lives on section 36, 2 N., 15 W., exhibited samples of tough quartz, enclosing calcite crystals, which he says came from his farm. This may indicate the presence in the neighborhood of conditions favorable to the deposition of silver bearing ores, though the specimens exhibited were barren. The structure in that direction, as reported by Mr. Hooper, agrees with what was observed in sections 33, 34, and 35, and, as the strike of the beds would cross this belt, the writer's opinion is unfavorable with regard to the occurrence of silver in this region.

The conditions under which the ores occur in the Kellogg mines, and the present uncertain relations of the folds in Pulaski county south of the Arkansas river, make it very difficult to predict closely the locus of silver deposition. But the following generalization is possible from knowledge gained by the Survey, viz: *The territory adjoining the intrusive rocks is the most liable to yield argentiferous ores.* Further exploration is needed, and the time has come for detailed study. While it is not improbable that galena and associated minerals more or less rich in silver may be discovered in new fields in this county, the chances are not so great that every report of a "find" can be accepted without the careful scrutiny on the ground by an experienced geologist and mineralogist.

SALINE COUNTY.

The sentence italicized in the preceding paragraph applies forcibly to the adjoining county of Saline, in which there are only two districts, so far as yet ascertained, offering any prospect of success in the search for silver. Both of these are more or less closely connected with intrusions of crystalline rocks. In neither of the areas have silver ores been actually mined, and there is much uncertainty concerning their occurrence.

The Rabbit Foot Mine.—The Rabbit Foot mine, section 33, 1 S., 15 W., worked for nickel, lies in a fault crevice, in a situation suitable for silver deposition, if there has been a source of supply. From present indications, and from the study of much of the surrounding county, the prospect of the discovery of argentiferous ores does not seem flattering, although the granitic rocks appear not far from Benton. See also page 34. There is a chance of reward for diligent search over the area yet unexplored, but the developments heretofore made do not lend much encouragement.

The North Fork of the Saline River.—In townships 1 N., 15 and 16 W., there are structural features which have opened passages for the deposition of such metallic minerals as may have been supplied from below. The granitic (?) intrusions, the metamorphic action, and the fault fissures are all evident, and the only question now is whether the heated waters had access to any silver bearing magma. One thing which is apparently favorable is the discovery of zinc blende in a seam in rock float in the bed of the North fork in section 26, 1 N., 16 W. This was collected by the writer, but it could not be found in place. In the black shale for a great distance along the creek, quartz beds appear at intervals. These have much the character of veins, and some have been worked as such without revealing any metallic ores. Mr. Shaw, residing in the neighborhood, claims to have discovered galena in one or more of these openings, and Mr. Geo. McAllister has seen fine samples taken from a locality three miles from his house in section 36. If the specimens which are said to come from this region are authentic, there is probably a district here which may be fairly compared with the Kellogg area in Pulaski county. After an examination of a limited territory no satisfactory conclusions could be reached. The possibility of the existence of good ore-bodies in the region, however, cannot be denied, and doubts can only be removed by detailed examinations extending over two or three townships.

GARLAND COUNTY.

There are but few places in Garland county where excavations have been made with a view to mining silver ores. Gold has been sought in numerous places without reasonable expectations, but as no considerable amount of silver was reported by assayers, only a small number of "prospects" have been regarded as producers of this metal. Had the favorable reports of certain individuals been trustworthy, there is no reason why a large number of mines might not have been successfully worked in this county, for the deposits which were claimed by them as argentiferous elsewhere, are abundant here, and in all essential respects they present similar features. Only a few mistakes of this kind have been made, however, in Garland county.

The Shippey Mine and the Sumpter Claim in the rear of the Grand Avenue car stables present no serious mining difficulties, and rich returns would have been forthcoming long ago, if the reported assays had been substantiated to the extent of one-tenth or even less. The real silver contents of these lodes have been carefully ascertained by the Geological Survey and are clearly shown in Table I. Much useless expense and many futile attempts to get any returns prove the correctness of the statements here made. The masses of coated quartz, however, which lay in the little gulch below the Shippey mine in the summer of 1887, do indicate something of value provided they belong there. The very thin incrustation of "gray copper" upon these masses, if traced to its source, might possibly lead to its discovery in workable quantity. At any rate, such a deposit has not been found, and the structure in that neighborhood is not favorable to the accumulation of thick masses of ore.

The Mozambique tunnel has been run upon a local deposit of impure iron ore segregated from a stratum of reddened shale, and nothing was found in the region that can be called a silver ore. The indications are in no sense favorable for the production of this metal.

The Golden Crown shaft is somewhat more favorably situated, but its product is inferior and shows little sign of improvement. The assays reported by Mr. Snyder as the best obtained by him were not such as to warrant mining.

The Linyear lode seems to have been located as a quartz crystal mine, for which purpose it is of some value. The occurrence of galena and copper pyrites, though rare and in minute crystals, may serve as a suggestion that better deposits are below or in the surrounding region, but evidences of such deposits are lacking as yet.

HOT SPRING COUNTY.

No indications of silver bearing ores occur in this county, so far as known. A few prospects have been worked, but the products have not been in any sense argentiferous, although some of the investors have fully believed that they were mining such material. The most probable district for the discovery of ores of this class, is the northeastern portion of the county, though the prospect is not good.

MONTGOMERY COUNTY.

Some of the conclusions, with all the important facts observed, have been detailed in chapters VIII and IX, but they will be discussed here as a whole. The reader is referred also to the remarks under the headings "Golden Wonder belt" and "Gray Eagle belt" in chapter VIII, and to the evidence presented in chapter XVI as to the absence of gold in the deposits along those axes.

THE BEAR CITY REGION.

The Golden Wonder Axis does not present any features which imply any considerable dislocation of the strata, a condition which seems to have been almost essential to the production of silver ores in Arkansas. The rock mined as ore along this belt is a bedded deposit of tough quartzose material, and no claim has been made that it carries workable proportions of silver. It contains no foreign mineral of any kind, and this fact precludes the occurrence of silver in it. See Table I for assays.

The Gray Eagle Belt, upon which the Lost Louisiana mine and No Man's mine are situated, at Bear City, contain rocks which have been claimed as silver bearing. None of them, however, justify such supposition, and there is nothing in the workings along this belt that can be properly regarded as an ore of silver or lead. The only resemblance to such minerals in any of the products is one of appearance only. The "red mud" and red and somewhat purple earths that occur in pockets and crevices in the hard rock might be mistaken for "carbonates" by persons whose knowledge of mineralogy is but slight; but they are wholly different minerals, containing no silver, as is shown by the assays reported in Table I. These soft ores are oxides of iron and manganese. Some of the stockholders of the Lost Louisiana Company were made to believe that they are "tellurides," and therefore very rich. As stated in chapter XVI, not a trace of tellurium, the basis of tellurides, has been detected by any trustworthy assayer to whom these substances have been submitted.

The collections made at the Lost Louisiana and No Man's mines comprise all the rocks classed as ore, and the results of their assays are given in Table I., Nos. 66 to 79. In the cases of both these mines, as well as in other openings in this region, the excavations are run so as to crosscut the formations, and the whole mass of rock removed, together with the adjoining portions upon both sides, have been regarded as ore. This method of work is the one commonly employed. Instead of cutting drifts or sinking shafts upon some vein or bed, tunnels are frequently run with or against the dip, traversing many successive rock layers, all of which are regarded as ore.*

Smelting Ores.—A good smelting ore is one which carries enough lead, or copper, to readily collect the silver without requiring a very high temperature for complete fusion. If, as is the case with the Lost Louisiana quartzite, there be a high percentage of silica or other earthy gangue matter, such a heat will be necessary for fusion that there will be loss of metal in the fumes; and unless such mixtures be employed as will neutralize the action, a further excessive waste will arise from the combination of lead with silica in the slag. But it is impossible to secure perfect fusion of a very large proportion of silica (quartz) by the use of ordinary fluxes, without acquiring a temperature too high for the saving of the metals contained in the ore. In common practice with the blast furnace, therefore, ore mixtures are made to carry at least 15 per cent. of lead, and this is altogether too low a proportion for quartzose ores. In the West lead is not paid for unless it reaches an average of 20 per cent. of the ore, and such grades of siliceous ore are only smelted by admixture with those richer in lead. Under special conditions, by adapting the process to one's needs, it might be possible to save silver enough to yield a profit, by using less lead, but the steps necessary to that end are decidedly not those which were taken by the persons who proposed to smelt the Lost Louisiana product.

In the first place, this rock carries no lead; in order to smelt it, the proper fluxes being used, not less than 500 pounds of lead must be added to each ton. Supposing that the best galena ores could be obtained, the admixture of about one ton to every three tons of the Lost Louisiana product would be required. Thus, if the assays of this material reported by certain assayers be admitted, the general average of the lead (?) ores of the region is such as to make it necessary to mix them with the Lost Louisiana ores in equal quantity in order to get a smelting charge of ore. Even then the results of treatment would not be economical, as the low percentage of lead would entail heavy loss of metal in the slag, as well as in the fumes. But when the fact is considered that the assays referred to, at least so far as they affect the supply of ores in large lots, are not to be relied upon, it will be seen that the idea of smelting in this region is chimerical. Besides this, the rock carries no silver nor any mineral which can be separated from the gangue.

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*No Man's tunnel has been made transversely to the dip, and it has cut more than a dozen layers of stratified rock, none of which are ores, but widespread members of the millstone grit.

The Ozark Mine yields a larger quantity of black shale and black earth, which is properly styled "black mud." Large returns were expected from this, and it is said that a number of tons was hauled nine miles to the smelter, at Crystal Springs. In this instance, as in many others, there were two untenable grounds of hope: First, the high assays reported were fictitious; and, secondly, the estimates of profit were wholly unsupported.

The basis of the belief in this so-called ore was an assayer's report that it was rich in lead. It was also claimed that it had been thoroughly tested at Joplin, Missouri, and that the person making the test was satisfied of this fact. Had the first item been true, it would have required an average of not less than 60 per cent. of lead to enable buyers to pay $1 per ounce for the silver contents without deductions, and this under very much more favorable conditions than those now existing. The cost per ton for mining would be at least $5. An ore carrying 40 per cent. of lead and 15 ounces of silver would be barely marketable at a profit. It is clear that any ore of lead must have a higher specific gravity than the rock in which it occurs, when that rock is a very common one. The base of the Ozark product is a black shale, finely comminuted, with a specific gravity of 2.5887. The same material carrying but 20 per cent. of lead would have a specific gravity of 4.326. The specific gravity of the Ozark black ore (?) determined in the Survey's laboratory is only 2.4438, about the same as the shale, which it really is.* Besides this, it shows no lead whatever by assay, and as it carries no silver, it is worthless.

General Conclusions Concerning Silver in the Bear City District.—After the descriptions in chapter VIII, it is evident that the claims east of Bear City and those near the Ozark mine are as barren as those here noticed. Throughout the whole courses of the Golden Wonder and Gray Eagle axes no developments have been made which warrant the belief that any valuable silver ores occur within working distance of the surface. As to the workings which lie west of Bear City, separate discussion is necessary except in the cases of those which come under the same category as the Lost Louisiana and the Ozark. The Atlas and Monarch appear to be properly included with those already considered, while the Accident Mining Company's shaft is not far removed from the Ozark in the character of its ore.

The Accident Tunnel.—The Phœnix Mining Company, whose stock was listed at the New York Mining Exchange, has never had any product that can be called merchantable ore. It has been claimed that many assays of the rock showed it to be very low grade, running from 3 ounces or less to 10 ounces per ton in silver. No one who can judge of the presence of lead, would ever seriously report it in this "Accident ore." The rock occurs in several qualities, but each is a tough grit without signs of mineralization, and the workings have been run to crosscut the whole series. The Bartlett smelter purchased by

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*The lead in the shale would be in the form of a sulphide. Twenty per cent of lead, when reduced, would therefore come from—

20 per cent lead having sp. gr.	11.37
3.32 per cent sulphur having sp. gr.	2.00
76.68 per cent shale having sp. gr.	2.583
100.00	

The specific gravity of the shale containing this amount of lead would therefore be 4.326.

the company was supposed to be able to reduce the ores at a profit without admixtures aside from the limestones (siliceous dolomites) of the neighborhood. These "Accident ores" are exposed over a very wide area in Arkansas. In very few places have they attracted any attention except where they are inclined at a high angle.

The Southeastward Extensions of the Preceding Belts.—In the southern half of Montgomery county, the prolongations of the Golden Wonder, Gray Eagle and Accident axes are defined, with much the same characteristics as have been here described. Their peculiarities are fully explained in chapters VIII and IX, and the continuations of the same folds through other counties in the southwest are outlined in chapters X and XI.

From the developments in those regions, if the writer's tracings of the structural lines be correct, the dislocation along the Accident axis in Sevier county has been sufficient to produce conditions favorable to the deposition of ores which may carry silver. This does not appear to have been the case in Montgomery county, at least in the northern half; but it is possible that here the underlying shales may also have undergone a similar series of disturbances, which have only resulted in the simple folding of the grits above. If so, there may be a chance of discovery of metalliferous deposits at considerable depths below the present Phœnix workings. At the same time, it must be said that there are no such indications north of Pike county, so far as our present knowledge goes, although there are good exposures of the black shales in this belt. Probably diligent prospecting may be rewarded by other discoveries, if attention be confined to those portions of the axis in which these beds occur at the surface.

THE SILVER CITY REGION.

The syncline between the Accident axis and the Broken Rock axis may be taken as the boundary line of the Silver City region upon the east, topographically and otherwise, although it has not been recognized as such in the laying out of the mineral districts for legal purposes. West of this there is a very material change, and the history of the district shows that something substantial was at the bottom of the early developments made in this tract. There are real ores here, some of which carry very profitable proportions of silver. In a few cases large returns have been made from the excavations of pockets of high grade mineral. The indications are such that it is reasonable to expect that the Silver City region may yet become a silver producer of considerable importance. But this is far from saying, as many claim, that the existence of such ores in paying quantities has been demonstrated. On the contrary, the money that has already been expended in working has not been returned to the investors, and there are no mines in the district that are paying expenses to-day. Unfortunately, the geological structure is such that shafts or slopes must be used in mining and very little depth can be attained without encountering water in excess of ordinary pumping facilities. Thus the expense of exploration is very great, and, the risks involved in the undertaking being considerable, there has been no heavy outlay of capital in any instance. The returns from the most extensive work have not been such as to tempt investors to make large expenditures with the uncertain prospects of gain.

Unfortunately, the work thus far done has often been based upon a misunderstanding of the conditions. A very full description of the mines and "prospects" has been given in the first part of this report.* In nearly all of these the metalliferous deposits lie imbedded in the strata between rock layers with a southeastward dip, as in the Kellogg mine in Pulaski county, though less regularly. The miners have almost invariably sunk shafts, which, in such cases, have cut through the ore-bodies and passed into barren rock. In one notable instance, that of the Minnesota mine, at Silver City, a large chamber has been excavated in the mineral body and extended below it like a shaft, but instead of exploring downward upon the dip, a prospecting tunnel was run so as to crosscut the underlying strata, in a direction opposite to that indicated by the inclination of the ore mass.

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*See headings, "The Silver City Mining Area" and "Broken Rock Belt," chapter VIII.

For these reasons and others, including the abandonment of the old mines and the present inaccessibility of the deeper workings, it is not possible now to use the explorations made as a very important factor in the problems concerning future developments. But there are enough natural and artificial evidences upon which to base a very fair judgment.

The Deposits Classified.—There are two classes of ore-bodies within this area, viz: 1st. Those which are practically interbedded, or which occupy spaces between more or less displaced beds, so as to have a semblance of conformity to the stratification. 2nd. Those which fill crevices, generally transverse to the strata. The latter type appears to be represented in part by the vein of the Eureka and Virginia claims of the Rubicon Mining Company, although such structure is rather in the nature of "leaders" or "feeders" branching from the main ore-bodies. The Walnut mine, however, is a good example of such a deposit as is indicated under 2nd head. The surface portions of other accumulations may have much of the same character, but the greater portion of the workings in the district appear to be essentially of the first class. The minerals are of nearly the same composition in all the deposits, but the metallic ores are usually scattered in pockets or but sparsely disseminated in the gangue. This makes mining hazardous, and although a few small bonanzas carrying exceedingly rich silver ores have been struck, there has been as yet no instance of a steady output from any mine. The environment of the mineral aggregations is such as to indicate very favorable conditions for the deposition of galena and zinc blende highly charged with silver, and the discoveries heretofore noticed imply that there is a deep seated source of such ingredients. The only question is whether enough of these bonanzas can be expected to repay the cost of the inevitable "dead work" in searching for them. While this must still be regarded as an undecided matter, the work thus far done is, in a measure, encouraging, and yet not enough so to justify the expenditure of very large sums of money in exploring new ground. There is but one way, in the writer's opinion, in which the future of this country as a mining region can be definitely settled, and that is by the discovery near the surface of new bonanzas which may yield prospectors sufficient funds to make further explorations. If enthusiastic men, who have faith in the district as an ore producer, will spend the money obtained from the marketing of rich pockets of ore in further developments, under competent advice, it may be that paying mines can be established. But it is very certain that none but the most inexperienced capitalist can be induced to invest money enough to really develop such mines here, merely upon the story of an exhausted pocket. If capitalists desire to put large sums of money into the testing of these ore-bodies, they cannot do better than to expend a considerable proportion of their funds in the preliminary study of the situation by a thoroughly skilled mining engineer who understands how to adapt his methods to the problems in hand, and who must not necessarily follow one method of work under any and all circumstances.

These deposits cannot be explored in depth without providing for pumping and ventilation, and eventually a reasonable amount of timbering will be required. Wood is abundant in most places and labor is not excessively high, although much of it at present is unskilled. Under competent superintendence, the money expended will not be wasted, whatever may be the results. Until such work has been done, it will be impossible to predict the outcome. From a geologic standpoint, there is good reason to believe that future returns may be as high as those of the past, or better, in some of the older mines; and there is hardly a doubt that good "prospecting" will be rewarded by other discoveries. But the outlook from an engineering standpoint depends wholly upon the plans adopted in development. Slopes instead of shafts will be required upon most of the deposits, and the explorations must be carried on in the directions indicated by the structure.

There is no region in the United States where the services of an experienced mining engineer are so necessary as in the Silver City region. Much of the work of excavation and timbering thus far done, has been excellent, but unfortunately it has been largely based upon erroneous views of the nature and position of the ore-bodies.

Probably the least expensive and the most promising work that could be done would be the pumping out of the upper portions of old shafts, filling in, if necessary, the abandoned workings, and continuing the explorations downward by slopes upon the deposits. This, and the permanent discarding of the notion that every little speck of decomposed pyrites, and every red or green or yellow stain is a "bromide," "iodide" or "telluride," yielding fabulous amounts of silver, will give a very different outlook to the mining interests and prospects of this region, and whatever hope there may be for it will very quickly be made evident.

There is one other fact that should be indelibly impressed upon the mind of every operator or investor in this district, viz:—that specimen assays, as guides to the value of a mine or ore deposit, are practically of no value. This does not mean, however, as many infer, that a guess at value is as good or better than an assay; but the value of any mining property is only to be determined by the average of its whole product—an average, computed by one who has been trained to such work, from assays made by skilled chemists. There are often principles involved in assaying which only a thorough chemist can appreciate. Moreover, assayers, as such, are not concerned with the determination of mine values, and they merely report the results of tests made upon what is submitted to them, without, in any way, expressing opinions as to quantity or the cost of working.

The Southwestward Extension of Broken Rock Axis.—There is a prospect of valuable discoveries in the course of this belt, where it has not been well explored in the southwestern portion of Montgomery county, though but little can be said of the actual conditions existing over that area. Probably the best "finds" will be made in places where the black shale forms the country rock.

The Blue Mountain Fold.—The western limit of the Silver City basin is really the syncline between the Blue Mountain and the Big fork anticlines. Thus the Broken Rock and the Blue Mountain folds, with the intervening area, constitute the district in which favorable results may be reasonably expected; and this belt, from the Ouachita river to the southwest corner of Montgomery county and beyond in Pike, Howard and Sevier counties, comprises all the silver bearing territory of which we have any certain knowledge, except the undefined territory in Pulaski county, and, possibly a tract in Saline county—at least so far as the thirteen counties under review here are concerned. Within the main belt, the greatest "expectancy" from present indications, attaches to the line of the Blue Mountain fold. The Waterloo mine, near this axis, is one of the best illustrations of the type, and it would be a good place for solving the problems connected with mining in the region.

PIKE AND HOWARD COUNTIES.

From what is said in chapter x, it will be inferred that the portion of Pike and Howard counties which carries the extension of the Silver City belt is favorably situated in some respects for the occurrence of silver ores. This belt seems to widen eastward as it passes southward, so as to include a part of the Accident axis also. That this is the case in Pike county is not certain enough to be stated here, but reports to that effect are current, and in Howard county the fact is evident in places observed by the writer. The district in Pike county which is included in this review is not promising as a prospecting field for silver, chiefly because the tough grits and the thick post-tertiary deposits cover the shales so deeply that the mineral bodies, if they exist, do not appear frequently at the surface. In Howard county the environment is even less favorable for the purpose, but here erosion has been more serviceable to the prospector in certain localities.

CHAPTER XIX.

General Conclusions Regarding Silver.

Nature does not always supply in ore deposits a well assorted collection, but, on the contrary, it is rare to find them in such combinations that little labor and skill will suffice to mine and mill them, and to extract the metal.

The classification of the ores of silver must depend upon the purposes of the classification. From a chemical point of view they may be divided into :

A. Real silver ores, or those in which silver is the principal element, and,

B. Argentiferous ores, in which the silver exists as a variable and non-essential ingredient.

With reference to the manner of their formation they may be classed as:

I. Ores of igneous origin, or those formed by fusion or sublimation.

II. Ores of aqueous origin, precipitated or otherwise formed from solutions.

They may also be divided into :

1. Native silver;
2. Oxidized ores;
3. Sulphuretted ores;
4. Miscellaneous ores.

The metallurgist distinguishes further between "dry ores," which carry but little or no lead or copper, and "smelting ores ;" while the miner must appreciate the difference between marketable ore, non-paying ore that may eventually become available, and waste ore.

These classifications suggest the range of technical knowledge and experience essential to the correct interpretation of the geology of the silver bearing minerals, and to the economic and judicious handling of these various ores. The skillful mining engineer must therefore have, or constantly endeavor to obtain as thorough knowledge as possible upon the following points:

I. The nature of the ore-body and the manner of its formation.

II. The natural conditions surrounding the deposit.

III. The quality and variety of silver ore.

IV. The peculiar character of the ore in question.

V. The methods of exploring and developing an ore-body, however irregular.

VI. The means and methods of extracting ore; of drainage, and of ventilation.

VII. The classification, assorting, concentration, and other mechanical treatments of the various classes of ores.

VIII. The correct sampling and assaying of ores.

IX. The best modes of reduction of ores of the different kinds.

X. The cost of mining, and all other collateral expenses.

These ten points will be discussed briefly with reference to the silver bearing tracts of the western central portion of the State.

I. *An Ore Body and Its Formation.*—An ore-body is an accumulation of one or more minerals in a regular or irregular mass in the earth. It may occupy cavities or crevices previously formed in a rock or series of rocks; it may be regularly interbedded, filling the gaps between strata forced apart; the mass may have been formed by the sudden or gradual change of pre-existing rocks; or it may have been forced into its place by other means. There are, of course, numerous irregularities which may ensue, but it rarely happens that extensive deposits, due solely to some generally acting cause, will vary in essential particulars at different points, however many secondary causes may induce local peculiarities. If, then, the geologist has traced a given form of structure over a wide area, and if he has found the same general results at all points, he may

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This mode of reasoning leads to the supposition that the Kellogg ore-bodies, in Pulaski county, will yet be found in their extended course; because: First, they lie in a district which does not seem to change its aspect in either direction for a a number of miles from the mines; and secondly, there is an apparent absence of anything to cause local action where the the ore has been found. Again, in the case of the conclusions formed concerning Montgomery county, and the region to the southwest, the folds, that are here regarded as barren throughout, show no signs of valuable silver ores at any point where they have been examined, and the lines which are productive near Silver City are equally so elsewhere, with marked indications, however, of local variations.

The ore-bodies in the Kellogg district are apparently interbedded, while those of the Silver City and Silver Hill districts, more likely, fill the fissures produced by axial faults. It is a very significant fact, also, that the tendency of all the silver ores is to appear upon the southeastern slope of the anticlines, and, as far as observed, the strike of the deposits is practically identical. Moreover, all the deposits yet discovered are within the limits of the black shales, and, as a rule, they do not extend upward into the overlying grits. The Silver City area has relics of hot springs which account for the local modifications there observed, while the special, or secondary features are less marked in the Silver Hill district. The latter region probably represents more nearly the typical features of the ore deposition along the Blue Mountain axis, but the chemical geology of the belt cannot be fully worked up without more study in the field. All that can now be predicated is, that zinc sulphide and antimony sulphide are presumably constant products, while copper sulphide is, perhaps, more abundant in Sevier county. But this generalization is of no great value, because we know but little of the deposits except near the surface.

The really important consideration now is the probable conditions existing at greater depths. The ore masses owe their positions to agencies acting from below. It is equally evident that aqueous deposition, and not igneous, has been in operation in the past, although a certain amount of quasi-igneous action may have heen necessary to produce the conduits for the mineralized solutions. The source of the metalliferous product is deep seated, for we know of no group of rocks in Arkansas at or near the surface, that can supply such material. The chances are, therefore, that the concentration of the precious metals, as far as the average mass is concerned, will be greater at some depth below the surface. This is the more probable from the fact that the terranes supposed to underlie the outcroping rocks present as good conditions as do those exposed. On the other hand, the action of hot springs, in the north, and the presence of the cap of thick and impenetrable grits in the south may both have exerted an influence similar to that described, so that an indefinite zone below the concentrated surface deposits may be more or less impoverished. These are some of the uncertainties attendant upon mining over this area, and the developments made heretofore have been so placed that the questions are not yet settled. So far as the evidence goes, however, it cannot be said that it is very unfavorable, although it must be admitted, after considering all the facts available, that much of the profit to arise in the working of these ores is likely to ensue from the presence of other metals besides silver.

II. *The Natural Conditions Surrounding the Deposits.*—The environment of these deposits is not the best for the accumulation of regular and extensive ore-bodies. The distribution will probably be found to be irregular and the deposits pockety. This, of course, does not preclude the possibility of their being valuable.

III. *The Quality and Variety of the Ore.*—The ores that carry the silver are rather numerous, but perhaps enough lead or copper is present in most places to make them smelt well, if carefully assorted. This, however, must be determined af-

high grade mineral, which cannot well be estimated. But in the Silver City belt the only fair method of testing a property is by its record of total production. If an average sample were made of a bonanza, the quantity factor—the most important of all—could not be used as a basis for calculation, because it is not possible to determine how many such pockets there are to the fathom, nor even whether other pockets are of the same grade. It is also manifestly unfair to make an average of the whole deposit in such cases, because in practice the gangue is not saved with the ore. The true criterion is the profit realized per unit of excavation, a complex item, and one which may vary greatly from month to month. Such a test, however, would not necessarily be a measure of the future of a "prospect" upon a pockety deposit.

If the ore be actually mined and ready for shipment, an assay of a few pieces taken at random or even by thoughtful selection is not enough to determine its value. The entire lot must be carefully "sampled" by one who thoroughly understands the principle of the process, successively crushed and cut down until a very small proportion is obtained which correctly represents the average of the whole. Specimen assays are usually of no value, except to show whether silver occurs in the ore, although a skilled person may often gain other information from such tests. Some persons think that the assay report of one specimen or of several is sufficient to indicate the worth of a mine, but this opinion is not correct. A specimen of ore, of the types already noticed, might yield by assay at the rate of 300 ounces of silver per ton, owing to the presence of some antimonial silver, while a larger lot might carry none of that mineral, and give an average sample of only fifty ounces, or less, per ton. From appearances only, no one can judge of the silver contents of any of the Arkansas ores.

IX. *The Methods of Reducing Ores.*—A question of great importance to settle before erecting reduction works, or deciding even upon the value of a mine, is the method of treatment best adapted to the ore. Many innocently suppose that a sample assay, made as described in the preceding para-

graph, is a guarantee of the market value of the ore. In other words, if one has fifty tons of ore, averaging $50 to the ton in silver, he thinks he should receive as the market value of the ore, exactly $2500. But this can only be true when it contains, in addition to the silver, enough of some other ingredient to pay all costs of transportation and treatment, as well as losses from the time it leaves the miner's hands until the silver has been extracted; and, in addition to this, an allowance must be made for reasonable profits to all engaged in the different stages of this manipulation. The best possible combination of circumstances, very rarely realized, would be one of the following:

I. A perfectly clean ore, containing no gangue whatever (or gangue valuable as a fluxing ingredient), composed wholly of one mineral (or of such a mineral mixture as would be thoroughly adapted to a given metallurgical process), with the proper works so near the mine that no transportation cost would be incurred.

II. A choice ore, or ore mixture, containing one or more minerals required in a given process, for which an extra price would be allowed, with the works very accessible.

III. In general, any set of conditions which will diminish the cost of treatment and increase the price received, at least enough to leave the silver as an untaxed asset.

The cost of treatment can never be brought to zero, and for this reason the total value of all the marketable ingredients of an ore can never be realized, except when the works may allow a trifle more than the actual intrinsic worth for a particular quality which they need to mix with other ores. In such a case, the extra bonus must, of course, be charged up in the reduced price paid for ores lacking the desired quality.

It is a ruinous policy to erect works before the development in a district has given a guarantee of a sufficiently large output of the requisite character for the process adopted, and it is also necessary to know thoroughly the nature of the ores within reach, and to be assured of a permanent supply before deciding what process to adopt. There has been far too little

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work done to make this possible in any part of Arkansas, but it seems probable that eventually a lead smelting plant might do well near Little Rock, drawing its supplies from a wide area. The time for this, however, has not yet come.

Where silver ores are smelted, the works are compelled to make heavy extra charges for treating those which contain a high percentage of zinc, and this must exert a very important influence upon the methods to be finally adopted, if future development warrant the erection of reduction works. Where the zinc blende can be readily saved separately this should always be done.

X. *The Cost of Mining and of Collateral Expenses.*—The cost of mining and reducing silver ores in Arkansas should not be great. Skilled labor is not abundant, but can easily be procured; living expenses are light, and water and timber are abundant, excellent and cheap. The conditions imposed by geologic structure are such as to cause some difficulties in mining, but the rocks to be attacked are not very hard nor very liable to displacement, if the excavations be carefully timbered. Upon the whole, if managed well, there is no reason why the total cost should not be small enough to justify the working of ores as low in grade as can be treated successfully in other parts of the United States.

What is most needed in the silver areas is exploration to greater depths; in other words, development. Let us hope that this, rather than the opening of numerous new "prospects," may characterize the near future. The successful outcome of work in the deeper portions of two or three properties, that will probably reward diligent prospectors, if the ore-bodies be closely followed, will give a greater impetus to mining industry than the uncovering and exhausting of a large number of surface "bonanzas."

THE DEPOSITION OF THE ARKANSAS SILVER ORES.

There may be those who will fail to understand how it is possible for silver ores to be produced in paying quantities under circumstances which have left the same depositories barren of gold. It has been shown that the conditions for gold deposition that have been lacking are chiefly the vital ones of supply, and the restriction of the conduits to narrow confines, but that in some other respects the environment is not inimical. From the fact of the occurrence of the silver bearing deposits in comparatively narrow belts, and from other considerations, it is to be inferred that these accumulations are the results of special or local conditions. The high assays of common sedimentary rocks reported by certain assayers must be ruled out of any fair discussion of the origin and character of real ores, for the conclusions we have reached concerning gold in such situations are even more applicable to silver.

The silver that occurs in the Arkansas argentiferous deposits is all in the nature of an accessory ingredient of some other metallic ore, usually galena or zinc blende; and these matrices occur in veins or vein like bodies, in districts where faults have been produced. The conditions necessary for the deposition of gold were present in the past, but its practical absence from the silver districts indicates barrenness of the strata from which the materials held in solution were gathered. It must be equally evident that lead, zinc, and silver were not wholly absent from the same collecting ground.

The processes enumerated as involved in the accumulation of gold are mostly applicable to the deposition of silver, but there are various conditions which might act to transfer silver before they had become active enough to collect the gold; and besides this, there are many modifications of the processes, and some special methods of depositing silver, which would probably have no effect in the case of gold. The conditions favorable to silver deposition in the districts where it occurs, were of two kinds, having differed in the Kellogg area in some respects from those that were effective in the Silver City tract.

In the Pulaski county tract, the results of the uplifts and of the fractures of the strata appear to have reached their maximum during the period in which the east-west axes were produced, but one or more of the ancient north-south folds may have extended beneath the district. The subsequent latitudinal upheaval tilted the strata and probably opened fissures or passages into the deep seated interior. The quartz and quartzites were deposited in these as in other areas of similar history, but the metallic ores were apparently unable to reach any point which is now exposed by erosion until a later period, when the diagonal axes were established. The result of this third system of disturbances in this region was comparatively light as far as the plications of the strata now at the surface are concerned, but the fracturing and faulting were very considerable. During this era of dislocation the zone of fusion was nearer the surface than in the previous upheavals, and thus the conditions suitable for the deposition of the metallic ores were presumably at their best, if, as is probable, there was then a good capping of the grits or quartzites, which do not now close the old conduit. The occurrence of all the conditions over wide areas is not a necessary result of this history, and yet with our inability to determine the deeper structure at most points for lack of good exposures, it is not possible to state whether there may or may not be other similar situations. The most favorable directions for "prospecting" have already been given, and important new discoveries will probably be made in the Kellogg district. Hap-hazard search may be rewarded by accident, but he who enters the field best equipped with a knowledge of the geologic environment will be most liable to succeed.

The Silver City and Silver Hill districts, in one sense, are not so favorably situated, because the influence of the latest, or diagonal, disturbance has been more dominant than the earlier ones, and the ore deposits are apparently only such as have been infiltrated into splits, cracks and cavities in the quartz seams since the dislocation and shattering of that material. These pursue a general course coincident with the axes, but are more or less irregular and scattered in distribution. It is often under such conditions that the richest silver ores occur, but their successful exploitation involves heavy expenditures. The more regular bodies, which presumably exist at some undetermined depth below the surface, do not lie directly beneath the ore-bodies previously reported; that is to say, the dip of the strata is such that the outcrop of any deposit is not vertically above the position which it occupies in depth.

TABLE I.

Assays for Gold and Silver.

A large number of "prospects," besides the workings enumerated in this table, were visited and examined. Numerous rock exposures and little strippings were also noticed, but in such cases the material was always like one or other of the samples assayed. For tests made for gold and silver in rock chiefly valued for its metallic contents, see Tables II, III and IV.

The material of Nos. 1-181 was collected for the Geological Survey by Theo. B. Comstock, unless otherwise stated.

No.	LOCALITY.	COUNTY.	MATERIAL.	Gold, ounces per ton.	Silver, ounces per ton.	REMARKS.
1	One mile w. of Rock creek	Pulaski	"Float" quartz	Trace	0.	Trace of copper.
2	Section 20, 1 n., 13 w.	..	Ferruginous quartz	Trace	0.	Trace of copper.
3	Section 23, 1 n., 14 w.	..	Quartz	Trace	0.	Trace of copper.
4	"Fletcher diggings"	..	Manganiferous limonite	Trace	1.	
5	Kellogg mine, German slope	..	Galena	Trace	30 to 60.	Average assorted ore running high in lead.
6	Kellogg mine	..	Freibergite	Trace	788.	Selected sample
7	Kellogg mine, German slope, upper w drift. See also Nos. 182-190	..	Zinc blende	.....	18.	
8	McRae mine, section 30, 1 n., 13 w	..	Shaly pyritous ore with little galena	0.	3.5	
9	Section 36, 1 n, 16 w., old diggings near McAllister's	Saline	Quartz with serpentine	0.	0.	
10	Near Shaw's, section 26, 1 n., 16 w.	..	Quartz	0.	0.	
11	Section 5, 1 s., 17 w.	..	Limonite	Trace	0.	
12	Bradfield's, same section as No. 11 and near it	..	Impure limonite	Trace	1.	
13	Extension of Blocher lode, on Cedar creek	..	Quartz	0.	0.	Has patches of serpentine.
14	Eureka lode, Cedar creek	..	Quartz	0.	Trace	
15	Sandcarbonate mine	..	Quartz	0	1.	Crucible assay.
16	Sandcarbonate mine	..	Quartz, same as No. 15	0.	1.	Scorification assay.
17	Sandcarbonate mine	..	Sand, clay, quartz, etc	0.	0.	Average of mine product.
18	Section 26, 1 n., 15 w.	..	Quartz	0.	Trace	
19	Glenpatrick lodes, Bertie shaft	Garland	Ferruginous quartz	0.	Trace	
20	Same locality as No. 19	..	Similar to No. 19	Trace	0.	
21	Glenpatrick lodes, Monarch cut	..	Siliceous sinter	Trace	0.	

TABLE I.—*Continued.*

No.	Locality.	County.	Material.	Gold, ounces per ton.	Silver, ounces per ton.	Remarks.
22	Glenpatrick lodes, Nickel Plate opening	Garland	Siliceous sinter	0.	0.	
23	Glenpatrick lodes, Patsy's Pride shaft	..	Siliceous sinter	.08	0.	
24	Shippey mine	..	"Gouge" and sand-rock	Trace	0.	
25	Shippey mine	..	Quartz	0.	0.	
26	Shippey mine	..	Rusty quartz	.04	0.	
27	Back of Grand Avenue car stables	..	Graphite shale and "black mud"	Trace	0.	Traces of copper
28	Section 23, 2 s., 19 w., Pleasant Run	..	Rusty quartz	.06	0.	
29	Section 1, 4 s., 19 w., s. e. quarter of s. e. quarter	..	"Black mud"	0.	0.	
30	Section 3, 4 s., 19 w	..	Fissile quartz	0.	Trace	
31	Section 10, 4 s., 19 w	..	Iron ore	0.	Trace	Silver 0.2 oz. per ton.
32	Same locality as No. 31	..	Quartz, underlying No. 31	Trace	0.	
33	Section 13, 1 s., 20 w., (n. w. ¼ of n. e. ¼) Lamb lode	..	Manganese ore	0.	0.	
34	Lamb lode	..	Iron ore	0.	0.	
35	Section 6, 1 s., 20 w Golden Crown lode	..	Quartz, south side of shaft, at bottom	0.	0.	
36	Golden Crown lode	..	Same as No. 36	0.	0.	
37	Golden Crown lode	..	Last ore taken out prior to August 5, 1887	Trace	Trace	
38	Section 2, 1 s., 20 w., Snyder's claim, s. face of Blakeley Mountain	..	Red sand	0.	0	
39	Snyder's claim	..	Yellow sand	0.	0.	
40	Section 22, 2 s., 20 w. Mozambique tunnel	..	Ferruginous streaks	0.	0.	
41	Mozambique tunnel	..	Same as No. 40	0.	0.	
42	Mozambique tunnel	..	Quartz	Trace	Trace	
43	Section 1, 3 s., 20 w., West Mountain	..	Quartz	0.	0.	
44	Section 2, 3 s., 20 w., West Mountain, Wikel's claim	..	Pyrite	Trace	0.	
45	Same locality as No. 44	..	Pyrite shale	0.	0.	
46	Section 31, 1 n., 21 w., Riley lode	..	Quartz (main body)	0.	0.	
47	Riley lode	..	Quartz, split streak	0	0.	
48	Cooper creek	..	"Accident ore"	Trace	0.	
49	Section 17, 4 s., 19 w., (s. e. ¼ of n. e. ¼)	Hot Spring	Pyritous rock	0.	0.	
50	Section 17, 4 s., 20 w., (n. w. ¼ of n. e. ¼) Garland County Mining Company's tunnel	..	Graphite shale shown by the miners as example of "best ore"	0.	0.	Chiefly graphite
51	Section 19, 4 s., 20 w	..	Quartz	0.	0.	
52	Section 30, 4 s., 20 w., Alpha lode	..	Quartz	0.	0.	Samples from two different cuts.
53	Same locality as in No. 52	..	Quartz	0.	0.	

TABLE I.—*Continued.*

No.	LOCALITY.	COUNTY.	MATERIAL.	Gold, ounces per ton.	Silver, ounces per ton.	REMARKS.
54	Buena Vista lode, s. w. ¼ section 30, 4 s., 20 w	Hot Spring	Quartzose manganese ore	0.	Trace	General average
55	Section 15, 4 s., 21 w., Una lode	..	Quartz	0.	Trace	Some pyrolusite
56	Section 22 (or 27) 2 n., 23 w	Yell	Iron sinter	0.	0.	Incrustation from spring.
57	Bear City, 'Aughey's stamp mill.'	Montgomery	Selected Golden Wonder rock from crushing floor	0.	0.	Ordinary crucible assay.
58	"Aughey's mill"	..	Same sample as No. 57	0.	0.	*By Mr. Aughey's formula.
59	Golden Wonder mine	..	Quartzite, etc.	0.	0.	Average 'ore' sent to Aughey's mill, Bear City.
60	Golden Wonder mine	..	Same sample as No. 59	0.	0.	By Aughey's Golden Wonder formula.*
61	Golden Wonder mine	..	Tough quartzite	0.	0.	At time of its collection Mr. Aughey called this "especially rich ore."
62	Golden Wonder mine	..	General rock adjoining the so-called ore	0.	0.	
63	Golden Wonder mine	..	Test sample	0.	0.	
64	Golden Wonder mine	..	Test sample, same pulp as No. 63	0.	0	By Aughey's formula *
65	Golden Wonder mine	..	Same pulp as No. 63	0.	0.	Reported by Prof. R. H. Richards, Mass. Inst'ute Technology, Boston, Mass.
66	Lost Louisiana mine	..	Average, from breast and 50 ft. back in south "drift"	Trace	0	Crucible assay.
67	Lost Louisiana mine	..	Same sample as No. 66	0.	0.	By Beam's L.* L. form. No. 1
68	Lost Louisiana mine	..	Same as No. 66	Trace	0.	Tellurium, none. Assay by P. de P. Ricketts, N.Y.
69	Lost Louisiana mine	..	Average from shaft to within 50 feet of breast, s. "drift"	0.	0.	
70	Lost Louisiana mine	..	Average n. "drift"	0.	0.	
71	Lost Louisiana mine	..	Same sample as No. 70	Trace	0.	By Beam's Lost Louisiana Formula No. 1 Faint traces of gold.*
72	Lost Louisiana mine	..	100 ft. from shaft, s. "drift"	0.	0.	Called "best ore" by Mr. Aughey.
73	Lost Louisiana mine	..	Wad (bog manganese ore)	0.	0.	100 feet s of shaft in south "drift."

*See note and formula at the end of this table.

TABLE I.—*Continued.*

No.	Locality.	County.	Material.	Gold, ounces per ton.	Silver, ounces per ton.	Remarks.
74	Lost Louisiana mine	Montgomery	Wad (purple)	0.	0	Selected by Mr. Buck as "rich telluride ore." It shows no trace of tellurium.
75	Lost Louisiana extension	..	Hard rock from several cuts	Trace	0	
76	No Man's mine	..	Ochreous earth	0.	0	Called "red mud."
77	No Man's mine	..	Graphitic, black earth	0	0.	Called "black mud."
78	No Man's mine	..	Black rock below No. 77	0	0.	
79	No Man's mine	..	Sample of the hard grits	0	0.	
80	Outcrop in road, half mile n. of Bear City	.	Quartz	0.	0	
81	Silver Spray lode	..	Quartz-rock	0	0.	Known locally as "Gray Eagle ore."
82	Silver Spray lode (different cut from No. 81)	..	Quartz-rock	0.	0.	
83	Golden Seal lode	..	Quartz-rock	0	0.	
84	Mammoth lode	.	Iron sinter	Trace	0	
85	Mammoth lode	.	Quartz	0	0.	
86	Ozark mine		Quartz-streaks	Trace	0.	In the cross-cut.
87	Ozark mine	.	Quartz	0.	0.	Outside of tun'l
88	Ozark mine	..	"Ore streak"	0.	0.	Near middle of cross-cut.
89	Ozark mine	..	Iron sinter	0.	0.	
90	Ozark mine	..	Earthy material in drift, reddish yellow	0.	0.	Known locally as "sand carbonate."
91	Ozark mine	..	Similar to No 89, from another place in the drift	0.	0.	
92	Black Chief "prospect"	..	Average of rock	Trace	Trace	
93	Accident Mining Co.'s shaft	..	Hard rock	Trace	0.	
94	Accident Mining Co.'s shaft	..	Soft rock	0.	0.	Regarded by the miners as the "best ore"
95	Accident Mining Co.'s shaft	..	"Black mud"	Trace	0.	Graphitic.
96	Phoenix Mining Co's Accident tunnel	..	"Accident ore" (compare Nos. 48, 113, 114, 139, 162, 164)	0	0.	Millstone grit.
97	Metaline Town site.	..	Concretion	0.	0.	
98	Section 6, 2 s., 28 w	..	Quartz	0	0.	Nos. 98-106 do not represent average ore in any case. The mines were mostly filled with water and the assays given here are only rough approximations of what the ores will yield when fairly assorted. The value of the properties will depend upon the relative proportions of ore and "dead
99	Section 6, 2 s., 28 w	..	Quartz, different bed from No. 98	0.	0.	
100	Section 18(?), 1 s., 24 w	..	Quartz	0.	0.	
101	Silver City, Minnesota mine	..	Samples from dump, showing galena and zinc blende	Trace	36.	
102	Silver City, Minnesota mine	..	Quartz, with spots of green and red mineral, in place	0.	1.5	
103	Silver City, Waterloo mine	..	Zinc blende and galena from vein	Trace	23.	
104	Silver City, Waterloo mine	.	Black shale	0.	0.	
105	Silver City district, Montezuma mine	.	Galena, etc., from ore house	0.	31.	

TABLE I.—*Continued.*

No.	Locality.	County.	Material.	Gold, ounces per ton.	Silver, ounces per ton.	Remarks.
106	Montezuma mine...	Montgomery	Quartz	0.	0.	rock," at present a very uncertain element. The quartz & shale assays are fr'm rock in place.
107	Walnut mine	..	Galena & zinc blende	Trace	17.	
108	Silver City district, Eureka lode.........	..	"Black mud"...........	0.	0.	
109	Eureka lode	.	Galena & zinc blende	Trace	19.5	
110	Waterloo mine. (Specimen furnished by postmaster at Silver City)......	..	Specimen of rich ore, said to have come from the old "bonanza" now worked out..................	Trace	346.	
111	Six miles from Mt. Ida on road to Black Spring......	..	Ferruginous quartz...	0.	0.	
112	"Ficticious" lode, Mt Ida and Black Spring road.........	..	Siliceous iron sinter...	0.	0.	
113	Section 23, 3 s., 25 w. From shaft for mining purposes...	..	"Accident ore".........	0.	0.	
114	Same locality as No. 113	..	"Accident ore," different from No. 113	0.	0.	
115	Caddo Gap	..	Rock same as in Golden Wonder mine, No. 59	Trace	0.	"Aughey's * Golden Wonder formula."
116	Shield's creek. "Copper lode," s. w. quarter section 2, 5 s., 25 w.........	Pike	Brittle, fine grained black shale ("black mud")	0.	0.	No copper.
117	Near No. 116.........	.. ..	Similar to No. 116...	0.	0.	No ccpper.
118	Section 4, 7 s., 30 w., May shaft............	Sevier...........	Mixture of 3 samples for average...........	0.	Trace	2½ per cent lead.
119	Section 5, 7 s., 30 w., Conway tunnel...	.. ..	Quartz	0.	0.	
120	Section 20, 7 s., 31 w. Otto mine...........	.. ..	Average samples including gangue......	Trace	1.2	By fire assay yields 81 per cent of antimony and lead.
121	Otto mine, w. drift...	.. ..	Black shale, containing antimony ores	0.	Trace	Lead 3½ percent.
122	Otto mine.........	.. ..	"Blue mud" "gouge" containing much antimony ore.........	0.	0.	
123	Davis mine, Silver Hill district.........	.. ..	Galena, chalcopyrite, zinc blende (specimens)	Trace	81.	
124	Silver World mine...	Polk	Pyritous shale.........	Trace	0	
125	Silver World mine...	.. ..	Pocket of 6 in., about 22 feet from mouth of tunnel. Ferruginous	Trace	0	Small quantity of copper. Traces of tin.
126	Silver World mine...	.. ..	W. drift, 250 ft. inside of tunnel. Ferruginous......................	0	0.	Traces of copper

* See note and formula at the end of this table.

TABLE I.—*Continued.*

No.	LOCALITY.	COUNTY.	MATERIAL.	Gold, ounces per ton.	Silver, ounces per ton.	REMARKS.
127	Silver World mine...	Polk	Azurite in quartz, 250 ft. inside of tunnel mouth	Trace	0.	Traces of copper
128	Silver World mine...	.. ..	From drift w., 300 ft. inside tunnel.........	0.	0.	Considerable manganese.
129	Silver World mine...	.. ..	Main body of shale for 400 feet	0.	0.	Traces of nickel and cobalt.
130	Silver World mine...	.. ..	White "horse-tooth" quartz, 400 ft. inside tunnel	0.	0.	
131	Silver World mine...	.. ..	For 550 ft. inside tunnel. Black shale...	0.	0	
132	Silver World mine...	.. ..	Selected Nos. 125 and 124	Trace	0.	3.8 per cent copper.
133	Section 1, 3 s., 29 w., Adams & Jackson lodes	.. ..	Iron and manganese ore..........................	0.	0.	
134	Section 9, 3 s., 29 w., Hazel branch lode	.. ..	Ferruginous ore with little manganese...	0.	0.	
135	Section 8, 3 s., 30 w., Caledonia (Durham's) lode.........	.. ..	Quartzose, with very little galena	0.	0.	Trace of lead.
136	Same section as No. 124. Queen of the West lode. (Durhams)..................	.. ..	Largely pyrite.........	0.	0.	Traces of zinc and little manganese.
137	Section 9, 3 s., 30 w., Argentiferous lode	.. ..	Shale and schistose rock. So-called "ore"......................	0.	0.	No lead.
138	Same as No. 137, Worthington's......	.. ..	Same sample as No. 137.........................	0.	0.	No trace of lead.
139	Same section as No. 137, Silver Star lode. Worthington's	.. ..	"Accident ore" millstone grit...............	0.	0.	No lead.
140	Same section as No. 137. Silver Queen lode. Worthington's	.. ..	"Ore" from e. tunnel	0:	0.	No lead.
141	Same as No 140......	.. ..	Same sample as No. 140.........................	0.	0.	No trace of lead.
142	Same locality as No. 140	.. ..	"Black mud," w. tunnel	0.	0.	Small quantity of cobalt.
143	Same as No. 142......	.. ..	Same sample as No. 142.........................	0.	0.	No trace of lead.
144	Silver Queen lode. Locality of 140...	.. ..	Limonite (red "gouge") w. tunnel	0.	0.	
145	Same as No. 144	.. ..	Same as No 144......	0	0.	No lead. No tellurium.
146	Same locality as No. 144	.. ..	Hard rock, w. tunnel, known as "ore"...	0.	0.	
147	Same as No. 146......	.. ..	Same as No. 146......	0.	0.	
148	Section 9, 3 s., 30 w., Cop'er Que'n lode Worthington's ...	.. ..	Rock stained with azurite, copper carbonate	Trace	0.	.2 per c't copper
149	Same as No 148 ..	......	Same as No. 148......	0.	0	Verylittle copper.

TABLE I.—*Continued.*

No.	LOCALITY.	COUNTY.	MATERIAL.	Gold, ounces per ton.	Silver, ounces per ton.	REMARKS.
150	Same locality as No. 148	Polk	"Golden Wonder" quartz and other hard rocks, all called "ore"	0.	0.	
151	Same as No. 150	..	Same as No. 150	0.	0.	No copper.
152	Section 24, 3 s., 31 w., west fork of Brushy creek, Canon Fisher lode	..	Tough quartzite or grit	0.	0.	
153	Section 28, 4 s., 31 w	..	Tough rock with galena, sphalerite and chalcopyrite furnished by J. T. Ward	.04	0.	
154	Towry lode. s. e. quarter, section 2, 5 s., 32 w	..	Black shale, called "ore" by owners	0.	0.	
155	Same as No 154	..	Same as No. 154	0.	0.	
156	Same locality as No. 154	..	Pyrite	Trace	0.	
157	Same as No. 156	..	Same as No. 156	0.	0.	
158	Same locality as No. 154	..	Pyrite selected by owner	0.	0.	Assay by Curtis Alexander, Antimony City, Ark.
159	One mile s. of Potter	..	Quartz "float"	0.	0	
160	Section(?) 1 n., 29 w. near base line	Scott	Tough quartz furnished by W. S. Wood	0.	0.	
161	Foran's Gap	.	Ferruginous streak, concretionary	0	0.	
162	Section 18, 4 n., 29 w.	..	Grit commonly considered auriferous	Trace	0.	
163	Same as No. 162	..	Same as No. 162	0	0.	
164	Section 24, 4 n., 29 w.	..	Grit, apparently identical with No. 162, being tested in an arastre. Contains specks of pyrite. Compare Nos 176, 162, 165, 179	Trace	0.	
165	Same as No. 164	..	Same as No. 164	Trace	0.	
166	Section 16, 1 n., 30 w.	..	Manganese ore	0.	0.	Manganese 72 per cent.
167	Section 35 (or 26) 1 n., 30 w	..	Iron ore, oxidized, with much pyrite	Trace	0.	
168	Section 18, 3 n., 31 w. Belt lode near Cauthron	..	So called "ore." Rusty quartz and clay "gouge"	0.	0.	
169	Same as No. 168	..	Same as No. 168	0.	0.	
170	Section 17, 5 n., 27 w. Peacock lode	..	General average of so-called "ore"	Trace	0.	
171	Section 18, 5 n., 27 w. (n. e. ¼). Aleck Thornton lode	Logan	Conglomerate with ferruginous cement	Trace	0.	
172	Same as No. 171	..	Same as No. 171	0.	0.	
173	Golden City, section 31, 5 n., 27 w., (n. e. of n. e) n. e. corner. Emily shaft	..	Black shale with calcite streaks. The so-called "ore"	Trace	0.	

high grade mineral, which cannot well be estimated. But in the Silver City belt the only fair method of testing a property is by its record of total production. If an average sample were made of a bonanza, the quantity factor—the most important of all—could not be used as a basis for calculation, because it is not possible to determine how many such pockets there are to the fathom, nor even whether other pockets are of the same grade. It is also manifestly unfair to make an average of the whole deposit in such cases, because in practice the gangue is not saved with the ore. The true criterion is the profit realized per unit of excavation, a complex item, and one which may vary greatly from month to month. Such a test, however, would not necessarily be a measure of the future of a "prospect" upon a pockety deposit.

If the ore be actually mined and ready for shipment, an assay of a few pieces taken at random or even by thoughtful selection is not enough to determine its value. The entire lot must be carefully "sampled" by one who thoroughly understands the principle of the process, successively crushed and cut down until a very small proportion is obtained which correctly represents the average of the whole. Specimen assays are usually of no value, except to show whether silver occurs in the ore, although a skilled person may often gain other information from such tests. Some persons think that the assay report of one specimen or of several is sufficient to indicate the worth of a mine, but this opinion is not correct. A specimen of ore, of the types already noticed, might yield by assay at the rate of 300 ounces of silver per ton, owing to the presence of some antimonial silver, while a larger lot might carry none of that mineral, and give an average sample of only fifty ounces, or less, per ton. From appearances only, no one can judge of the silver contents of any of the Arkansas ores.

IX. *The Methods of Reducing Ores.*—A question of great importance to settle before erecting reduction works, or deciding even upon the value of a mine, is the method of treatment best adapted to the ore. Many innocently suppose that a sample assay, made as described in the preceding para-

graph, is a guarantee of the market value of the ore. In other words, if one has fifty tons of ore, averaging $50 to the ton in silver, he thinks he should receive as the market value of the ore, exactly $2500. But this can only be true when it contains, in addition to the silver, enough of some other ingredient to pay all costs of transportation and treatment, as well as losses from the time it leaves the miner's hands until the silver has been extracted; and, in addition to this, an allowance must be made for reasonable profits to all engaged in the different stages of this manipulation. The best possible combination of circumstances, very rarely realized, would be one of the following:

I. A perfectly clean ore, containing no gangue whatever (or gangue valuable as a fluxing ingredient), composed wholly of one mineral (or of such a mineral mixture as would be thoroughly adapted to a given metallurgical process), with the proper works so near the mine that no transportation cost would be incurred.

II. A choice ore, or ore mixture, containing one or more minerals required in a given process, for which an extra price would be allowed, with the works very accessible.

III. In general, any set of conditions which will diminish the cost of treatment and increase the price received, at least enough to leave the silver as an untaxed asset.

The cost of treatment can never be brought to zero, and for this reason the total value of all the marketable ingredients of an ore can never be realized, except when the works may allow a trifle more than the actual intrinsic worth for a particular quality which they need to mix with other ores. In such a case, the extra bonus must, of course, be charged up in the reduced price paid for ores lacking the desired quality.

It is a ruinous policy to erect works before the development in a district has given a guarantee of a sufficiently large output of the requisite character for the process adopted, and it is also necessary to know thoroughly the nature of the ores within reach, and to be assured of a permanent supply before deciding what process to adopt. There has been far too little

work done to make this possible in any part of Arkansas, but it seems probable that eventually a lead smelting plant might do well near Little Rock, drawing its supplies from a wide area. The time for this, however, has not yet come.

Where silver ores are smelted, the works are compelled to make heavy extra charges for treating those which contain a high percentage of zinc, and this must exert a very important influence upon the methods to be finally adopted, if future development warrant the erection of reduction works. Where the zinc blende can be readily saved separately this should always be done.

X. *The Cost of Mining and of Collateral Expenses.*—The cost of mining and reducing silver ores in Arkansas should not be great. Skilled labor is not abundant, but can easily be procured; living expenses are light, and water and timber are abundant, excellent and cheap. The conditions imposed by geologic structure are such as to cause some difficulties in mining, but the rocks to be attacked are not very hard nor very liable to displacement, if the excavations be carefully timbered. Upon the whole, if managed well, there is no reason why the total cost should not be small enough to justify the working of ores as low in grade as can be treated successfully in other parts of the United States.

What is most needed in the silver areas is exploration to greater depths; in other words, development. Let us hope that this, rather than the opening of numerous new "prospects," may characterize the near future. The successful outcome of work in the deeper portions of two or three properties, that will probably reward diligent prospectors, if the ore-bodies be closely followed, will give a greater impetus to mining industry than the uncovering and exhausting of a large number of surface "bonanzas."

THE DEPOSITION OF THE ARKANSAS SILVER ORES.

There may be those who will fail to understand how it is possible for silver ores to be produced in paying quantities under circumstances which have left the same depositories barren of gold. It has been shown that the conditions for gold deposition that have been lacking are chiefly the vital ones of supply, and the restriction of the conduits to narrow confines, but that in some other respects the environment is not inimical. From the fact of the occurrence of the silver bearing deposits in comparatively narrow belts, and from other considerations, it is to be inferred that these accumulations are the results of special or local conditions. The high assays of common sedimentary rocks reported by certain assayers must be ruled out of any fair discussion of the origin and character of real ores, for the conclusions we have reached concerning gold in such situations are even more applicable to silver.

The silver that occurs in the Arkansas argentiferous deposits is all in the nature of an accessory ingredient of some other metallic ore, usually galena or zinc blende; and these matrices occur in veins or vein like bodies, in districts where faults have been produced. The conditions necessary for the deposition of gold were present in the past, but its practical absence from the silver districts indicates barrenness of the strata from which the materials held in solution were gathered. It must be equally evident that lead, zinc, and silver were not wholly absent from the same collecting ground.

The processes enumerated as involved in the accumulation of gold are mostly applicable to the deposition of silver, but there are various conditions which might act to transfer silver before they had become active enough to collect the gold; and besides this, there are many modifications of the processes, and some special methods of depositing silver, which would probably have no effect in the case of gold. The conditions favorable to silver deposition in the districts where it occurs, were of two kinds, having differed in the Kellogg area in some respects from those that were effective in the Silver City tract.

In the Pulaski county tract, the results of the uplifts and of the fractures of the strata appear to have reached their maximum during the period in which the east-west axes were produced, but one or more of the ancient north-south folds may have extended beneath the district. The subsequent latitudinal upheaval tilted the strata and probably opened fissures or pass-

CHAPTER XXIII.

Manganese.

There is a large amount of manganese in different localities within the counties of Pulaski, Saline, Garland, Hot Spring, Montgomery, Pike, Polk and Scott, and perhaps in others of the remaining counties examined. For special descriptions of the deposits and details concerning the modes of occurence of the ores the reader is referred to the following items:

The manganese district of Pulaski and Saline counties, described in chapters I and II., pp. 15 to 27.

The Lamb lode in northwestern Garland county, referred to in chapter VII, p. 74.

The Una and Buena Vista lodes, in Hot Spring county, p. 90.

The Lost Louisiana mine, in Montgomery county, p. 98.

The head of Shield's creek in the northern part of Pike county, p 129.

The Silver World mine and Ward's mine, Polk county, pages 151 and 155.

Section 1, 3 S., 29 W., in Polk county, p. 156.

Section 16, 1 N., 30 W., in Scott county, p. 169.

In the production of manganese Arkansas now ranks as the third State in the Union, Virginia and Georgia being the only others which, up to the close of 1887, had yielded any considerable amount of ores valued chiefly for this metal. The total production of Arkansas for the year 1887 is estimated at 5,651 tons.* This was all taken from the Batesville district in Independence county, which is outside of the region discussed in this report.

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*Mineral Resources of the U. S., 1887, p. 150.

There are few ores so uncertain in their development as those of manganese, and this fact makes it very difficult to estimate the future capacity of any area from the surface croppings alone. There are also many questions connected with the mining and the commercial utilization of the ore, which are dependent upon the variable elements of supply and demand, as well as upon the very uncertain relations of manganese to improvements which are constantly being made in various arts and manufactures. While the increased output has thus far kept pace with the gradually increasing demand, there has been a certain amount of progress in the direction of discovery and invention, which renders it very probable that larger quantities of the inferior grades may hereafter be made available.

An important use of manganese ore, for which only pyrolusite, or manganese dioxide, is directly or indirectly employed has been as a source of oxygen. This use, however, absorbs but a fraction of the manganese product of the United States. Fully three times as much is used in the manufacture of bromine and chlorine, the latter being subsequently converted into bleaching powder. A small amount of the best ore is also exported for this purpose. The purest grades of pyrolusite, practically free from iron, may be utilized in the manufacture of flint glass, for dispelling the greenish tint caused by iron. For all these applications the supply is liable to exceed the demand, owing to the possibility of recovering the ore from the waste without excessive loss, and of its repeated use in the same process. But there are other applications which bid fair to absorb eventually a much greater product than this country has yet yielded. For such purposes the lower grades of manganese ores containing iron in large proportion may, perhaps, be successfully used. These are commonly known in the trade as manganiferous iron ores. The dividing line between the manganese ores and the manganiferous iron ores adopted by the United States Geological Survey, Division of Mining Statistics and Technology, is at 44.252 per cent. of metallic manganese, which is equivalent to 70 per cent. of the dioxide, the lower

TABLE I.—*Continued.*

No.	LOCALITY.	COUNTY.	MATERIAL.	Gold, ounces per ton.	Silver, ounces per ton.	REMARKS.
174	Same as No. 173.....	Logan	Same as No. 173......	0	0.	Some pieces of copper caps used in blasting.
175	Same shaft as No. 173	.. ..	Pan washings from 4 pounds of "ore" No. 173..................	0.	0.	Panned by T. B. C
176	Same as No. 175......	.. ..	Same as No. 175......	0.	0.	Panned by T. B. C.
177	Golden City. Shaft SamFlor'nce lease Emily Co	.. ..	Pyrite nodules.........	Trace	0.	
178	Golden City. Golden Era shaft.........	.. ..	Pyritous concretions.	0.	0.	
179	Golden City. Golden Era shaft No. 2	.. ..	Millstone grit, apparently same as Nos. 162 and 164............	Trace	0.	
180	Same as No. 179......	.. ..	Same as No. 179......	0.	0	
181	Golden City, Arlington shaft	.. ..	Nodules of hard black shale............	Trace	0.	

It has been claimed that the characters of some of the materials here reported upon are such as to require special formulas in the assays. These materials have therefore been tested in various ways, including assays by the following formulas, from which unusual results have been claimed.

The reader is also referred to the *Engineering and Mining Journal* of July 28, 1888, pp. 63, 64.

"Aughey's Golden Wonder formula," by which 58, 60, 64 and 115 were assayed

Ore........................	**½ assay ton.**
Sodium carbonate.........	**1 assay ton.**
Flour.......................	**½ assay ton.**
Litharge....................	**½ assay ton.**
Pulverized borax glass	**4 grams**

Mix thoroughly, place in crucible, and tamp. Place on top:

1. Layer of pulverized silica,
2. ¼ inch layer of nitrate of ammonia,
3. Layer of ½ assay ton of litharge,
4. Cover of salt.

"Beam's Lost Louisiana formula No. 1," by which 67 and 71 were assayed:

Ore.......................	**½ assay ton.**
Carbonate of potash	**½ assay ton.**
Bicarbonate of soda......	**1 assay ton.**
Flour.....................	**¼ to ½ assay ton**

Place in crucible, tamp tight, cover with finely pulverized glass. Add ½ assay ton of nitrate of ammonia, a coating of borax glass, cover with test lead and finally with salt.

TABLE I.—*Continued.*

Additional Assays for Gold and Silver of Material not Collected by the Geological Survey.

The following additional assays, though not made by the Geological Survey or of its material, are doubtless perfectly trustworthy, though it is not always stated what the ore examined represents. Mr. Gibb, who has kindly furnished most of these assays, was personally interested in the Kellogg mine when the assays were made.

No.	LOCALITY.	COUNTY.	MATERIAL.	Gold, ounces per ton.	Silver, ounces per ton.	REMARKS.
182	Kellogg mine, "F. W. G., No. 94"...	Pulaski	Average galena ore...	....	26.6	Lead 31.1 per cent. Assayed by F.W. Gibb.
183	Kellogg mine, "F. W. G, No. 98"...	.. ..	Copper pyrites	Trace	7.2	Assayed by F. W. Gibb.
184	Kellogg mine "F. W. G., No. 99"...	. ...	Average zinc blende	....	0.6	Assayed by F. W. Gibb.
185	Kellogg mine, "F. W. G., No. 311"...	.. ..	Selected sample of galena	....	70.4	Assayed by F. W. Gibb. Lead 72 per cent.
186	Kellogg mine, "F. W. G, No. 493"...	.. ..	Selected gray copper, tetrahedrite	....	1112.	Assayed by F. W. Gibb.
187	Kellogg mine.........	.. ..	Sample of quartz......	0.	0.	Assayed by F. W. Gibb.
188	Kellogg mine.........	.. ..	Cube galena free from gangue..	....	$60 pr ton.	Lead 81 per cent.*
189	Kellogg mine.........	.. ..	Cube galena free from gangue..................	....	$52 pr ton.	Lead 77 per cent.*
190	Kellogg mine.........	.. ..	Selected tetrahedrite	....	$1232 pr ton	*
191	Silver City district, Zarelda mine......	Montgomery	First sample............	0.	0.	Nos 191 to 198 inclusive, assayed by F.W. Gibb, but localities not vouched for by him.
192	Silver City district, Zarelda mine......	. ..	Second sample..........	0.	0	
193	Silver City district, Zarelda mine	..	Third sample...........	0.	0.	
194	Silver City district, Zarelda mine......	.	Iron pyrites	....	11.8	
195	Silver City district, Zarelda mine . ..	..	Galena.......	....	40.3	
196	Silver City district, Walnut mine		Quartz, copper stain	....	99.3	
197	Silver City district, Walnut mine	..	Tetrahedrite	....	18 8	
198	Silver City district, Walnut mine	.	Selected galena.........	....	103.6	
199	Silver City district, Marga mine	..	Probably a carbonate	....	26 2	Collected and assayed by F. W. Gibb.
200	~~Bear~~ Silver City, Mammoth ~~lode~~ mine	.	... ...	....	7.	
201	~~Bear~~ Silver City, Mammoth ~~lode~~ mine		... ...	....	Trace	Assayed by F. W. Gibb.

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* These three assays, 188, 189 and 190, were reported by the assayer of the United States mint at Philadelphia, Pa., February 8, 1867, to George M. Howell, secretary of the Arkansas and Ohio M. and M. Co. The values are given in dollars; upon what basis, it is not stated.

CHAPTER XX.

Lead and Zinc.

The lead ores occurring in workable quantity in the region examined are so intimately associated with the zinc ores, and both of them are so closely linked with the silver ores, that it is unnecessary to devote much space to their separate consideration. Wherever there has been a discovery of the "gray copper" silver bearing minerals in more than thin filmy deposits, galena has always been found, and sphalerite, or zinc blende, is an almost invariable accompaniment in the same or neighboring ore-bodies. Copper pyrites is hardly less general, but the copper bearing minerals are not confined to such situations, as the lead and zinc ores usually are in this region.

LEAD.

As may be inferred from the preceding statement, the districts from which the lead ores will be chiefly obtained are the Kellogg area in Pulaski county, which will perhaps be greatly extended by future discoveries, and the great tract southwest of the Ouachita river, lying between Broken Rock and Blue Mountain axes in Montgomery, Howard and Sevier counties, and crossing the southeastern portion of Polk county. The northeastward continuation of the latter district to an indefinite distance through Garland (?), Saline, Perry and Pulaski counties, is among the possibilities, but further examination is necessary in order to settle the question, as the writer's observations in that direction have been confined to a small area, over which the indications are not very favorable.

Claims made by citizens residing in Saline county, in township 1 N., 16 W., were investigated at the expense of Dr. W. E. Green, of Little Rock, who permits the Survey to state that these claims were but partially confirmed, although it must be admitted that not enough time could be given to the work to make a thoroughly conclusive report. So far as the discovery of lead in paying quantities is concerned, there was no valid evidence to that effect as late as August, 1888. Judging from the geologic structure, the situation may be as favorable for such occurrence as in the Kellogg district, and it is very desirable that a thorough examination be instituted. It may be worth knowing that the kind of deposits which this region presents is not liable to be merely local, and, in most cases, tracing along the strike will determine its continuation upon an alternate section of government land, if the original discovery be upon railroad land.

Galena is the only mineral of economic importance in which lead occurs in the region, at least so far as is now known. The "carbonate" ores, such as those which built up the city of Leadville, Colorado, have been supposed to exist in many places, and there are numerous deposits of red and yellow earths, especially in Montgomery county, which have been called "sand carbonates" by the mine workers. In the table of assays for lead, copper and zinc, at the end of this chapter, a number of tests of this class of material is given, showing that in no case has lead been detected. These so-called carbonates are all ochreous earths, made up chiefly of iron oxides, and sometimes containing more or less of manganese oxide also. They are of very low specific gravity, which would not be the case if they carried lead in paying quantity.

The reputed existence of lead in the light shales and black earths of the Bear City district has been attributed to the existence of wulfenite or the molybdate of lead. There is nothing whatever in the appearance of the material, its mode of occurrence, its weight, or its chemical composition, to justify this appellation, nor is there any speck of foreign mineral that can be mistaken for wulfenite. In many tests of this and similar material from other districts the only mineral beside the shale that gives character to the deposits is found to be graphite, although calcite, pyrite, etc., are occasionally present. No galena or other lead mineral has been detected in any of the samples of this kind, except as noted in Table 11.

The black earth of the Ozark mine was particularly famous around Bear City in 1887 as a lead ore. It was claimed that it had been thoroughly tested at Joplin, Missouri, and that it had yielded such good returns that the smelter had been erected at Crystal Springs mainly for the purpose of treating this earth. The material is finely comminuted black shale, yielding no lead.

The Kellogg mine, whatever may be its future yield of silver, must depend largely upon the lead in its galena ore for paying costs. If this and the zinc can be made to yield a small profit, the chances are good that the extra remuneration from the silver will be very satisfactory. As it will be both undesirable and impracticable to separate the silver ores from the galena, a lead smelting process must be adopted for the treatment of both. For some time to come it may be necessary to ship the output of these grades to St. Louis or some other smelting point, but if discoveries enough are made in the neighborhood, a plant at Little Rock or in the mining district may prove best. Much mining development will be required, however, before it can be known how permanent the supply really is, and whether it be all as pure as that now in sight.

To get the best possible results from the shipment of this ore it should be assorted closely to free it from gangue, but not so as to waste any appreciable portion of the silver minerals. Hand assorting is the only suitable process, unless quartz should occur in much larger proportions in the deeper workings.

The Silver City district may also become a lead producer of some importance, if continuous ore-bodies be found upon further development. The remarks relating to the Kellogg area apply even more forcibly to the Silver City district, but it can hardly be expected that the lead in these ores will pay a profit by itself. The dependence of this tract for a considerable period in the future must probably be the silver ores, although the lead and other metallic ores may be made to help out materially. Hand assorting is very essential.

Mechanical concentration will hardly be possible with such ores as now form the product, and too much assorting will result in waste. The best that can be done will probably be the rough division into two grades, one containing as much lead and as little zinc as it is possible to arrange without loss of silver. This is an indefinite mode of speaking, but not more so than necessary, as metallurgists will readily understand. After this grading of the ore separate markets will, of course, be sought for each portion, the lead stock going most appropriately to the smelters.

Somewhat irrespective of the silver contents, the richness and purity of a lead ore enhances its market value in a kind of geometric progression. This has been partially explained in the chapter on silver. The excessive presence of zinc upon the other hand is very detrimental in lead smelting processes. If the Silver City region should finally yield large quantities of the mixed ores, a combined process of lixiviation and other modes of treatment may become most suitable, but the time is not at hand for any strictly local plants to succeed.

The lead in the antimony district of Sevier county does not appear at its proper value in any analyses of the mixed ores. Although it may not be profitable now to make a separation before reduction, a small output of assorted galena might be had by this plan. The question of its profitableness will have to be decided wholly upon a knowledge of the relative proportions and market values of the mixed and separated minerals. The process can be carried farther with less loss than in the case of the Silver City ores.

The Silver Hill area appears to be subject to the same conditions as have been described for the Silver City tract, and probably no especial modifications will be demanded by the intervening unexplored territory, so far at least as the lead product is concerned.

There may be other districts in which galena will be found, but, unfortunately, large sums have been expended in running useless tunnels in rocks that have given no indications of any ore whatever. The Worthington mines south of Dallas have been quoted as examples of lead yielding workings. The samples of "black mud" and "red mud" from the argentiferous lodes, assays of which are reported in Table II, Nos. 67 and 68, as well as others from the same group of claims, are products in which Mr. Worthington himself told the writer that he had obtained lead by fusion in an improvised earthen ball or crucible.

The Silver World mine, also in Polk county, has been regarded as a producer of lead ore, but none of the rocks taken from the ore dumps show any workable quantity of the metal. In the mountains south of Dallas, in some specimens said to have come from Durham's claims, a little galena in quartz is visible, and a few other localities in Polk county have yielded similar pieces. As yet that country has not been thoroughly prospected. The chances of finding new lead deposits are fair, although all localities which now seem likely to yield good returns have been noticed here. There is hardly any ground for anticipating paying supplies of the metal from any other source than galena. If this does not occur in the deposits pronounced lead bearing, such deposits should at least be regarded with wholesome suspicion.

ZINC.

The only ore of zinc that has been mined in the region is sphalerite, or zinc sulphide, popularly termed zinc blende. The varities are chiefly two, but others occur. "Black jack," the most common, is what mineralogists term marmatite when it carries from one-fifth to one-half of its weight of iron sulphide, making the proportion of iron above 10 per cent. Ordinary zinc blende is usually of lighter colors, and a dull, yellowish or brownish product of the Kellogg mine is of this type. The latter carries more zinc, but the marmatite has usually near the minimum percentage of iron in this region. A very little calamine or zinc silicate, and some zinc carbonate or smithsonite are also found in connection with the lead and zinc ores, but usually not in important proportions. The sphalerite of the Silver City tract inclines more towards the sub-variety familiarly known as "rosin zinc." Besides the product of the Kellogg mines and the Silver City and Silver Hill mines, a small amount of zinc has been detected in some of the deposits in Polk county, but as yet, no bodies of ore have been discovered. Probably the source of the metal reported in the assay list is sphalerite, and it may be that diligent search will be rewarded by the exposure of masses of this mineral in new localities. Prospecting in such situations, however, should not be conducted carelessly, nor by making expensive excavations in a hap-hazard manner, but by tracing the deposites along the strike of the rocks in which they occur. The courses of the axes are clearly depicted upon the maps illustrating this report, and it will generally be advisable to pursue the indications within the area between the nearest two lines thus laid out. Often the best results will come from following only the one axis in which the more favorable showing is made. Another district which offers encouragement to prospectors is the area north of the base line upon the Saline river drainage, particularly in the basin of the north fork of that stream.

There is a very important distinction, economically considered, between the deposits of the latitudinal trend and those which lie in the diagonal belts.* In the districts where the east-west trends prevail, as in Pulaski and Saline counties, nature has separated the lead and zinc ores very advantageously for metallurgical purposes, or, perhaps, it would be more proper to say that they have not been mixed as undesirably as has been the case in the more irregular fissures of the Broken Rock axis. In the line of the Blue Mountain fault, a condition between the others is rather typical, and patches, or

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*For convenience of reference, the term *latitudinal* is applied to those folds and strikes which run approximately east and west; the north-south axes are, for the same reason, styled *meridional*, and the third lines of plications running northeast and southwest are denominated the *diagonal* trends. Map 1 gives examples of all the sets.

pockets, and sheets of zinc blende occur which are comparatively free from the other minerals of the belt, which, however, usually lie in the same conduits.

At present there is no reason to anticipate the discovery of workable deposits of zinc ore in Garland, Hot Spring, Scott, Logan or Franklin counties, unless it may be in some restricted locality, where the lowest deposits, geologically speaking, have been exposed by erosion.

The discussion upon lead in the first part of this chapter applies in a measure to zinc, and especially is this the case with all that relates to the preparation of the ores by hand and by mechanical means. But the metallurgy of zinc is an independent theme. The same difficulties which exist in the smelting of zinciferous lead ores prevent the economic reduction of zinc from its ores by this process. But, if the lead and the silver are not to be considered, methods can be adopted for saving the zinc which are not wholly practicable in silver-lead smelting. There are works in St. Louis, Chicago, Kansas City and other places where zinciferous lead ores are purchased and successfully treated, but they are usually compelled to make a much lower schedule for argentiferous zinc ores than for other qualities, so that it will ordinarily pay the miner to go to considerable trouble and expense to rid his ores of their zinc bearing minerals, if he have an available market for the latter. For these reasons, the zinc blende of the Kellogg district, naturally separated or easily removed by hand, and the artificially removed product from the western districts, can best be sent to special zinc reduction works, if they be not eventuallv treated in Arkansas. The economy of one plan over the other, however, will be dependent upon circumstances which have not been sufficiently investigated. The zinc deposits of the northern counties of the State have not as yet been examined by the Geological Survey, and a thorough knowledge of that region and its resources will be necessary to a discussion of the best methods of working and marketing the deposits of the region here treated of.

CHAPTER XXI.

Copper, Tin, Nickel, and Cobalt.

COPPER.

The only economic source of copper as yet made manifest is the mineral chalcopyrite, or copper pyrites, which is intimately associated with galena in nearly all of the known occurrences of that mineral. In some cases it can be separated by hand without much difficulty, but too much of this treatment might entail serious loss of silver. There is a great advantage in effecting this separation where the copper mineral is abundant, because ore buyers do not usually pay for both lead and copper in the same ore.

When they do so, there will commonly be a reduced schedule for each metal which will practically amount to about the same thing as non-payment for one of them. This applies particularly to the smelters, where the mixed ores of this class must necessarily go. The most appropriate reduction methods for lead and copper sulphides are radically different, and it is, therefore, best to remove the copper pyrites if it occur in any considerable amount. There is no great quantity of this mineral in the region, and yet, as will be seen in Table II, there are many places where traces of it occur in the rocks. This is most noticeable, perhaps, in the area of the latitudinal trends, but the application of the remark is general. Incrustations of azurite, the blue copper carbonate, are common in the black shales, but these are of no commercial importance. In connection with these, in rare instances, a very little native copper in minute scales, in black shale, and, at times, small crystals of blue vitriol (chalcanthite) have been observed. These all deserve mention here, chiefly because, in the eyes of many, their striking contrasts and the surrounding rock are taken as evidence of richness out of all proportion with the facts. The azurite incrustations upon quartz in the Silver World mine, in Polk county, and in other places upon the shales, will coat a knife blade with a thin film of copper if only rubbed across it. The amount of this mineral which is present in a ton of the rock mined is too small to have any commercial significance. One ton of the pure mineral might be worth, say $90, but the market value of one ton of the incrusted rock and mineral together, as saved in the form of ore at the mine would be nothing, as the valuable portion could not begin to pay the cost of separation. The sample recorded in Table II as yielding less than four per cent. of copper was very carefully assorted to a grade such as could hardly be realized upon a large scale, and this represents a value of not more than $7.00 per ton. In order to maintain an output of this grade, it would be necessary to reject at least nineteen-twentieths of the rock as it comes from the mine, leaving at a very high estimate, a value of 35 cents per ton for the original ore. But, in order to mine a ton of such material, several tons of other barren rocks must be removed, leaving for the average of the total product a very few cents. The copper product of this and similar mines has cut no great figure in the claims made for its resources, but as all the other material saved upon the dumps was worthless, some pains have been taken to determine the amount of this metal contained in the copper bearing portions. As indicating the presence of metallic substances somewhere in the neighborhood, the development of these Polk county mines has been useful. Traces of gold and silver, nickel, cobalt, zinc, and tin have been found in the Silver World product and all these, except tin, in one or other of the Worthington group of prospects. In the Silver World considerable manganese also occurs. There is, therefore, reason to believe that some kind of an ore belt runs through the region. From other indications and from observations through the district, it is the writer's opinion that it is a manganese tract worthy of further investigation. are, in the region examined, any deposits of co can be worked profitably for themselves alone, is, however, very improbable. The assays reported in Table II represent fairly the general situation. Traces of copper in quartz and other rocks may mean little or nothing, as pyrite often contains very small percentages of this metal, and that mineral is widespread.

TIN.

The only instance which has come to the writer's notice of even a trace of tin being actually discovered, is the slight indication of this metal reported by the Chemist of the Survey, in his assay of No. 74, Table II, the product of a ferruginous pocket in the Silver World mine. Upon a map prepared to show the positions of certain claims in the Silver City district, a line of lode locations near the summit of the long ridge, southeast of Silver City is marked "tin claims." This ridge was crossed not far from the western end of these claims, but nothing was seen which would justify the belief in the occurrence of this metal there. The same country rock was crossed in its strike in four or five other places at least, and material from equivalent rocks has been carefully tested without obtaining any reaction for tin.

NICKEL AND COBALT.

The description of the Rabbit Foot mine, given on pages 34 and 36, contains all that is known of importance concerning the occurrence of nickel at that point. The ore is millerite, or nickel sulphide, in capillary crystals, occurring in cavities and crevices in quartz enclosed in black shale. The deposit in which the mineral occurs is liable to run beneath the Saline river. The claim certainly deserves development, especially at its western end. The ore must be carefully assorted to yield a profit, as the average, as it comes from the mine, is low in nickel.

The following are the results of analyses, kindly furnished by Col. S. H. Whitthorne, President of the Saline County Mining and Improvement Company, of material said to have been taken from this mine.

A lot of 1991 pounds of the ore was sampled and assayed at the St. Louis Sampling & Testing Works, Prof. W. B. Potter, Manager, and it was found to contain:

Gold	0.02 ounces per ton.
Silver	none.
Nickel and cobalt	1.46 per cent.

Another sample reported upon by the same works contained:

Nickel and cobalt	1.64 per cent.

A lot of the ore was also examined by Dr. Albert E. Menke of the Arkansas Industrial University, who reports some cobalt and silver, and

Nickel	54½ pounds to the ton.

One average sample collected by the Geological Survey and examined in the Survey's laboratory did not run quite so high in nickel as the samples cited above, but there can be no doubt about the possibility of obtaining higher results by assorting the ore. The deposit is a very interesting one, and it may develop into a paying mine. This is all that can safely be said of it at present.

Traces of nickel and cobalt are not infrequent in a variety of situations, and cobalt, especially, has been reported in considerable quantity from some peculiar fragments said to have been taken from a deposit on the Ouachita river, south of Hot Springs. There is no large deposit of the kind there, although cobalt bearing minerals occur sparingly.

Cobalt is an almost constant accompaniment of the ores of manganese and antimony, but it has not been found to exist in them in large quantities, though it may often occur in small pockets.

CHAPTER XXII.

TABLE II.

Assays for Lead, Copper, and Zinc.

A large number of samples tested for lead, copper, and zinc show no signs whatever of the presence of those or other metals of value, but the tests have been made because the presence of these metals in the material has been reported and persistently claimed. Besides the special tests for the three metals—lead, zinc,and copper—most of the examples have been examined for tellurium, but no trace of it has been found in any instance. Other metals have also been sought, but in every case they were absent, unless otherwise stated in this table, under "Remarks." This statement, however, does not apply to iron when present merely as an impurity. Except when otherwise mentioned, the tests have been made by the Geological Survey, and the results have been checked by independent tests.

No.	LOCALITY.	MATERIAL.	PERCENTAGE.			REMARKS.
			Lead.	Copper.	Zinc.	
1	Kellogg mine, German slope	Selected galena....	78.	....	....	Trace of gold;silver, 60 oz
2	Kellogg mine, German slope........	Galena and copper pyrites...........	52.	12.	....	Not tested for gold or silver.
3	Kellogg mine, German slope.......	Selected copper pyrites	....	26.	....	Silver 31 oz. per ton.
4	Kellogg mine, German slope.......	Selected zinc blende	....	....	64.5	Silver 18 oz. per ton.
5	Kellogg mine, German slope.... ...	Carefully selected argentiferous gray copper. (Freibergite)	....	5.	Small Amount	Silver, 788 oz. per ton.

TABLE II.—*Continued.*

No.	Location.	Material.	Percentage.			Remarks.
			Lead.	Copper.	Zinc	
6	Kellogg mine	Said to be "average of 10 tons, but not sampled(?), sack of 95 pounds"....	....	....	62 5	Reported by F.W.Gibb. The lot of 95 lbs. sampled by Matthiessen & Hegeler Zinc Company, La Salle, Ill.
7	Kellogg mine.	Selected galena....	81.	.. ....	....	Silver, $60.00 per ton. Assay by U. S. mint assayer, Philadelphia, Feb. 8, 1867, from material furnished by G. M. Howell, Sec'y Arkansas and Ohio M. and M. Co.
8	W. of Kellogg mine, range 12 w........	Quartz.......... ..	....	Trace	....	
9	One mile w. of Rock creek, on upper Hot Springs road.	"Float" quartz....	.... .	Traces	... ...	
10	Section 20, 1 n., 18 w	Quartz, in beds.....	....	Traces	....	Trace of gold. Ferruginous.
11	Section 23, 1 n., 14 w	Quartz "float".....	.... ..	Traces	....	Trace of gold.
12	Section 26, 1 n., 16 w	Quartz, in beds, abundant	....	0.	......	
13	Section 36, 1 n., 16 w. Old diggings near McAllister's mill.	Quartz, with small patches of serpentine(?)....	0.	0.	0.	
14	Section 26, 1 n., 16 w	Black zinc blende, in "float"........	....	0.	56.	Silver, 9 oz. per ton.
15	Section 18, 1 n., 17 w. Cedar creek......	Quartz with serpentine..............	0.	0.	.. .	
16	Same locality as No. 15	Black shales	0.	0.	0.	
17	Rabbit Foot mine, section 33, 1 s., 15, w	Quartz, containing millerite....... .	....	0.	....	Some nickel.
18	Same locality as No. 17	Pyritous ore..... ..	....	Small amount	....	Some nickel.
19	Sandcarbonate mine, section 33, 1 n., 18 w............ ..	Siliceous sinter called "ore" by the miners....	0.	0.	0.	
20	Golden Crown lode, sections 6 and 7, 1 s., 20 w	Average "ore".....	0.	0	0.	
21	Mozambique tunnel, section 22, 1 s., 20, w	Quartz	0.	0.	0.	
22	Same locality as No. 21...... ...	Limonite streaks...	0.	0.	0.	
23	Same locality as No. 21................	Red, hematitic shale	0.	0	0	
24	Glenpatrick lodes, Hot Springs	Quartz from different openings......	0.	Trace	0.	Traces of gold.
25	Shippey mine, Hot Springs ..	Quartz	0.	Trace	0.	
26	Shippey mine, Hot Springs	Red and yellow sandy earth........	0.	Trace	0.	
27	On Mt. Ida road, rear of Grand Avenue stables	Pyritous graphitic black shale.. ...	0.	Traces	0.	Trace of gold.

TABLE II.—*Continued.*

No.	Location.	Material.	Percentage.			Remarks.
			Lead.	Copper.	Zinc.	
28	"Spanish diggings," north of Magnet Cove.	Samples of siliceous sinter, called "gold ore"	0	0.	0	
29	Another sample, same locality as No. 28.	Same material as No. 28	0.	0	0.	
30	Garland County Mining Co.'s tunnel. Section 17, 4 s., 20 w., n. w. ¼ of n. e. ¼	Graphite, called "rich silver ore"	0.	0.	0.	
31	Head of Copper creek, section 15, 4 s., 19 w	Iron ore, said to "carry gold"	0.	0.	0	
32	Near Magnet Cove, north	Pyrites, abundant	0.	Small amount	0.	
33	Una lode, near Light foot springs	Iron and manganese ore in quartz.	0.	Trace	0	
34	Buena Vista lode, Carbonate hill	Manganese ore in quartz	0.	0.	0.	
35	Alpha lode, near Carbonate hill	Quartz, called "gold ore"	0.	0.	0	
36	Headwaters of Little Mazarn, 4 s., 21 w	Ochreous red sand worked as "gold prospect" called "carbonate"	0.	0	0.	
37	Bear City, Lost Louisiana mine.	Altered quartz rock, called "smelting ore"	0.	0	0.	
38	Same mine as No. 37	Bluish wad, called "telluride"	0	0.	0.	
39	Same mine as No. 37	Ochreous iron and manganese oxide, also called "telluride"	0.	0.	0.	
40	No Man's mine, Bear City	Similar to No. 39, called "carbonate"	0	0	0	
41	Same mine as No. 40	Black earth, called "rich lead ore"	0.	0.	0.	See No. 44.
42	Golden Wonder mine	General rock, called "ore" and "telluride"	0.	0.	0	
43	Golden Wonder mine	Same as No. 42	0.	0.	0.	
44	Golden Wonder mine	Selected specimen	0.	0	0.	Assayed by "Beam" lead formula No. 1." See end of this table.
45	Mammoth lode	Limonite deposit, called "gold ore".	0.	0.	0	
46	Ozark mine	Product sent to smelter, called "lead ore," and "black mud"	0.	0.	0.	Repeated tests of the "black mud" and the "blue mud," show only graphite and shale. It gives no reaction for lead or molybdenum.

TABLE II.—*Continued.*

No.	Location.	Material.	Percentage.			Remarks.
			Lead.	Copper.	Zinc.	
47	Ozark mine	Same as No. 46	0.	0.	0.	By Beam's "lead formula No 1." See end of this table.
48	Accident Mining Co.'s shaft	So-called best ore. reported by local assayers as carrying 40 per cent of lead	Trace	0.	0.	
49	Phœnix Mining Co., Accident tunnel	"Accident ore"	0.	0	0.	Occasionally a very small amount of silver and a trace of gold.
50	Eureka lode, Rubicon Mining Co	"Blue mud," a mixture of graphite shale with mineral from shaft	Trace	Trace	Trace	
51	Eureka lode	Assorted ore, carefully picked specimens, largely galena	49	4	15.	
52	Walnut mine	Assorted galena ore	76.	2.	4.	
53	Montezuma mine	Large piece, assorted, from ore-house; galena and zinc blende	43.	1.5	14.	
54	Shield's creek. s. w. ¼ of section 2, 5 s., 25 w	"Black mud"	0	0	0.	
55	Same locality as No. 54	Same sample as No. 54	0.	0.	0.	By Beam's "lead formula No. 1." See end of this table.
56	Same locality as No. 54	Material like No. 54, different opening	0.	0.	0.	
57	May shaft, section 4, 7 s., 30 w. Sevier county	Average ore, galena and antimony ore, chiefly the latter	2.5	....	....	Traces of silver.
58	Otto mine, w. "drift" section 20, 7 s., 30 w	Black shale containing antimony ores	3.5	....	....	Trace of silver.
59	Otto mine	Not best ore	15.81	....	....	9.19 of antimony.
60	Otto mine	Average ore, without assorting, very siliceous	9.46	....	....	Antimony 21.54, silver 1.2 ounces per ton, gold trace.
61	Davis mine, Silver Hill	Galena, copper pyrites and zinc. Specimens	23.	7.	18.	Silver 17.5 oz. per ton.
62	Towry lode, near Hatton gap, Polk county	Pyrites	0.	Small amount	0.	
63	Section 28, 4 s., 31 w., Polk county	Specimen of quartz, with galena, pyrites, etc	2.	2.5	Trace	Furnished by Mr. Ward. Could be assorted much more closely, and the lead, copper and zinc separated.
64	Section 8, 3 s., 30 w., Durham's Queen of West lode	Quartz, with galena blende, copper pyrites	0.	Trace	Trace	

TABLE II.—*Continued.*

No.	LOCATION.	MATERIAL.	PERCENTAGE.			REMARKS.
			Lead.	Copper.	Zinc.	
65	Caledonia lode, section 8, 3 s., 30 w, (Durham's)	Crystals of galena, etc., in quartz....	Trace	0.	0.	
66	Worthington's argentiferous lode, section 9, 3 s., 30 w	Shaly "ore"...... ..	0.	0.	0	Mr Worthington claims to have obtained lead by crude methods of smelting from several of his rocks, but they show no signs of lead mineral.
67	Same as No. 66.....	Same as No 66 ...	0.	0.	0.	
68	Worthington's Silver Star lode	"Accident ore"....	0.	0.	0.	
69	Silver Queen lode. Worthington's mines	General product....	0	0.	0.	
70	Same locality as No. 69........	Red ochreous earth, or "red mud" ...	0.	0.	0.	Compare Nos. 36, 29, 40.
71	Same locality as No. 69	Black earth, or "black mud".....	0.	0.	0.	
72	Worthington's Copper Queen lode, section 9, 3 s., 30 w	Shale with stain of copper carbonate.	0.	2.	0.	
73	Same locality as No. 71.........	Quartz like that at Golden Wonder mine	0	0.	... ...	
74	Silver World mine	Ferruginous earth in pocket 22 feet from tunnel mouth.	0.	Small amount	...	Gold, trace; tin, trace.
75	Silver World mine.	Similar to No. 73. West drift 250 feet from tunnel mouth.	0.	Trace	....	
76	Silver World mine..	Copper carbonate (azurite) in quartz	... ...	2.	0.	Gold, trace.
77	Silver World mine..	Selected Nos. 74 and 75 mixed.... ...	0.	3.8	0.	
78	Emily shaft, Golden City	Black shale, just after blasting, caps not removed...	0.	2.	0.	The copper found in assays of ores from Golden City, Logan county, was found to be due to fragments of exploded blasting caps.
79	Same as No. 78 ..	Same as No. 78. Caps removed by washing	0.	0.	0.	

Inasmuch as it has been persistently claimed that some of the material reported upon in the above table as barren of lead, do carry that metal, tests have been made of it with the formula by which higher results are said to have been obtained. The following is the formula with which Nos. 44, 47 and 55 were tested:

"Beam's lead formula No. 1":

Ore	5 grams.
Calcium carbonate.............	5 grams.
Potassium cyanide..	5 grams.
Fine charcoal...................	100 milligrams.

Cover with borax glass, and insert a nail.

ores are the earlier ones, and that the richer manganese ores were originally of this class.

The Lamb lode, in the northwest quarter of the northeast quarter of section 18, 1 S., 20 W., represents a better grade of manganese ore than is usually found upon the diagonal trend outside of the "novaculite" environment, but this is hardly an exception to the rule, because it occurs in a locality where there has been a spring at some former time, and it is not far removed from a region of ancient hot springs. In the eastern portion of the Trap Mountains in Hot Spring county, wherever the quartz has been much altered, the situation is mineralogically very similar to that which appears near the base line in Saline and Pulaski counties, except that the dips are different in the two areas. The Una lode, on section 15, 4 S., 21 W., near Lightfoot Springs, and the Buena Vista lode in the southwest quarter of section 30, 4 S., 20 W., both contain some choice pyrolusite in quartz, but there is an essential difference between these outcrops and the others examined in that region. These two lodes are more like veins than is usual and they can hardly be brought into comparison with the generality of the manganese ore-bodies elsewhere. They agree with the Lamb lode in one respect, but in others, that occurrence more nearly resembles the manganiferous iron ores of this district. All three localities are among the highest beds of the terrane underlying the millstone grits, corresponding thus in their geologic horizons most nearly with the outcrops along the northern edge of the main manganese ore field of Pulaski county. Moreover, there was, at the Lamb, Una and Buena Vista outcrops alike, a difficulty in determining the true dip, though in every instance the weight of evidence seems to place them in the diagonal trends. There is one more point of difference, however, between the Polk county deposits and the others. This is that the pyrolusite not only occurs in separate bands, but as far as observations have gone, there do not appear to be the parallel bands of limonite, or manganiferous iron ores, which are a striking feature of the Pulaski-Saline manganese districts. It is said that "township 4 south, range

28 west, in Polk county, contains, in addition to large quantities of limonite ore running over fifty-six per cent. metallic iron, immense deposits of manganese ore, or pyrolusite."* It is very probable that failure to observe them in other places near each other, was due to the capping of siliceous rocks and the unfavorable exposures. This is all the more likely from the fact that the tracing of known occurrences of either ore along the structural lines indicated above often brings one to an observed locality of the other. In some cases, instead of limonite, a deposit of pyrites will appear about upon the same strike as the pyrolusite, but this does not necessitate any important change in the opinion stated. At the same time, there may be a scarcity of the iron ores in the "novaculite" areas without contradicting either Mr. Barnes or the writer, as the locality named in the quotation is really out of the altered quartz belt.

Pyrolusite very rarely occurs without some admixture with braunite, or manganese sesquioxide, popularly known as the "brown oxide of manganese." The pyrolusite is the black oxide, but what is popularly termed "black oxide of manganese" is usually a variable mixture of pyrolusite, braunite and iron oxides. Aside from the knowledge of the actual proportions of each mineral, and the total manganese contents of the ore, it is important for commercial purposes to determine the moisture and the percentage of silica and phosphorus. The water in the ores of this region is not excessive where they are taken in dry weather from bedded deposits near the surface or above the drainage of the country, but it frequently forms a large percentage of the freshly mined bog ore. The fine grained, porous ores absorb much moisture in wet weather, and it is always customary to thoroughly dry the samples for assay. The proportion of silica, if in the form of sand, may affect only the cost of preparation for market. In many cases, however, this mineral may be so intimately mixed with the ore as to render separation impossible at the mines. The percentage that can be allowed without rendering the ore unmarketable will depend upon the quality of the manganese minerals

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and other circumstances. Usually not more than 10 per cent. is permissible. But the presence of phosphorus is very injurious. A very little of this ingredient is a serious detriment to the commercial utilization of a manganese ore which cannot be used for other purposes than the manufacture of spiegeleisen or ferro-manganese. In this manufacture, however, the percentage of phosphorus is of less consequence than its regularity. It is a comparatively simple matter to work a high phosphorus ore, but the product cannot readily be kept uniform unless the supply be regular also. The Batesville ores have varied from .12 to .21 per cent. in phosphorus, and, as will be seen from analysis quoted here, the new deposits carry from 0.03 to 0.41 per cent. These latter, however, are not averages of production as are those from Batesville. The metallurgy of these new ores is usually so linked with the iron industry, and so much dependent upon the uncertain economic conditions of the future that it is impossible to make satisfactory predictions based upon the known facts. It would seem that the ores of this region compare favorably with those of the Batesville district, so far as surface indications may be trusted. The averages of assays of the product of that area are given by the United States Geological Survey from authentic sources at 44 to 60 per cent. for manganese, and .12 to .21 for phosphorus, with silica 1.5 to 5., where iron is from 1. to 6. The general run of the ores is, however, from 52.50 to 54.50 in manganese. The Polk county ores will probably run as high as this, and there is reason to believe that, if the total manganese contents be allowed in the Pulaski-Saline area, the product of easily assorted ore will not fall far behind. It must be borne in mind that only the binoxide tests have been given for the last named district, although there is a considerable admixture of braunite, and possibly of other manganese ores, in places.

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*Mineral Resources of the U. S., 1887, p. 148.

The continuation northeastward of the belt in which Ward's mine is situated was noticed in section 1, 3 S., 29 W., and the same series of enclosing rocks were crossed in another place southwest of the mine, which is in the southwest corner of section 28, 3 S., 30 W. The positions marked upon the maps are those in which more or less valuable deposits of these manganese ores are known to occur, but it is very probable that other discoveries will be made, while it is almost certain that the districts extend beyond the limits drawn for them.

The deposits of hard ore containing the most dioxide usually occur in beds or segregations between the black shale below and a layer of quartz or quartzite above. In a few instances a red or yellowish sandstone forms the cap rock, and sometimes the ore forms a net-work of partitions filling fracture crevices in the "hanging wall." The best ores of the bedded form may be expected, as a rule, in situations where the dip is greatest, say 40° and upwards, and where the siliceous cover is toughest and least like ordinary brittle quartz.

Those bog ores are best which occur in a black soil, and which are themselves of a black color, the most nearly crystalline and friable; and the more readily they can be separated from the brown and harder ores, the richer they are liable to to be.

The rather irregular deposits of wad and other manganese and manganiferous ores, such as occur in crevices and pockets in the neighborhood of Bear City, in Montgomery county, appear to be chiefly interesting as indications that other more valuable kinds may possibly exist in that district. The mining of these can hardly be made profitable, for they are not sufficiently abundant, or accessible enough to warrant the outlay necessary in the removal of their enclosing rock. Some manganese carbonate occurs in similar situations, but no important deposit of that mineral has yet been encountered in any of the workings.

Suggestions to Prospectors.—In searching for new deposits of the manganese ore in the region under discussion the prospector need have comparatively little difficulty or expense, if he will familiarize himself with the following simple rules, which are based upon the natural conditions under which all the known deposits occur:

I. Start from some place where a workable deposit of manganese ore exists. Note the character of the hard rock above the ore. Put in your pocket a piece taken from its natural position, with which to compare specimens elsewhere.

II. With a pocket compass follow a course, as nearly as possible, 70° E. of N. or 70° W. of S. (N. B.—These are compass readings for 1887-8.) If the hard rock can be followed, that is the best guide. Use the compass to guide you only when the rocks will not.

III. Keep always upon the same dip of the rocks. Clear away under the tough rock frequently with a pick, and search for ore between that and the black shale beneath.

IV. The highest position of the ore masses will always be above this, though usually near the upper limit. There may be more than one band, and it will be best to dig a little above the upper edge of the "float," and at other points if the mineral debris runs in belts. Keep a sharp lookout upon the hillsides for "float."

V. When crossing ravines or valleys examine the flats for bog manganese, which is sometimes only to be found by digging. The richest kinds are liable to be in the hills, towards which the mealy black ore becomes more abundant.

VI. The best gulches to follow for exposures, where you are not following a known bed, will always be those in which the streams run across the dip of the rocks. Examine every place where quartz or quartzose rock lies above black shales.

VII. If not practicable or convenient to observe rule I or II, use the maps of this report, and lay out your course by sections, along the lines marked "anticlines" and "synclines."

VIII. If rule VII be also impracticable, start from any point reasonably near a manganese deposit and go north or south until you get "indications" in bogs or "float" mineral, then proceed as in the other rules.

TABLE III.

Assays and Analyses of Manganese Ores.

NOTE—Assays Nos. 5 to 12 were not made for the Geological Survey and it is not known what thickness of vein they represent.

No.	LOCALITY.	MANGANESE.	IRON.	SILICA.	PHOSPHORUS.	ANALYST.
1	Caledonia lode, section 8, 3 s., 30 w	Considerable.	Chiefly	.....	....	Geological Survey.
2	Queen of West lode, section 8. 3 s., 30 w	Little	....	...	....	Geological Survey.
3	Section 1, 3 s. 29 w.	Much	Much	....	.....	Geological Survey.
*4	Ward's mine, section 28, 3 s., 30 w.....	60.66	Sesquioxide 1.43	1.00	. .	Geological Survey.
†5	Probably same as No. 4	58.86	0 00	9 02	.41	Assay by W. B. Potter and Regis Chauvenet & Bro., St. Louis.
†6	Probably same as No. 4...........	55 80	0 50	3 72	.03	
†7	Probably same as No. 4........	27 68	35.39	1.88	.23	
†8	Probably same as No. 4	52.23	4 40	3 29	.04	
‡9	Arkansas Development Company's property, as above, localities not given	53 10	..	3 00	13	
10	¶Same as No. 9 ...	71.20	..	2 77	Trace	Assay by Charles E. Wait
11	Same as No. 9	54.27	2.70	1 19	09	J. Blodget Britton.
12	Same as No. 9 . .	47	17.00	....	.06	Smithsonian Institution.
18	Section 16, 1 n., 30 w	61.89	Sesquioxide 2.28	2 00	....	Geological Survey. §

* Available oxygen, 14.40; manganese dioxide, 60.64; manganese sesquioxide, 32.07; baryta and traces of lime, 6 50

† Quoted in Mineral Resources of U. S., 1887, p 149. From Ward's mine, or from section 32, 4 s., 28 w.

‡ Average(?) of 26 specimens sent to Birmingham and Sheffield, England. Name of analyst not given. From Mineral Resources, 1887, p. 149.

¶ Average of 4 assays made by Professor Wait, at Missouri School of Mines.

§ Available oxygen, 13.26; manganese dioxide, 46.36; manganese sesquioxide, 46.75; alumina, undetermined.

No.	LOCALITY.	MATERIAL.	MANGANESE DIOXIDE.	ANALYST.
14	Section 14, 1 n., 14 w. Mann's diggings .	Hard bog manganese with much iron ore.... ...	16.10 per cent	Geological Survey.
15	Same locality	Black ore with little iron	63 42 ..	Geological Survey.
16	S. ½ of n. w. ¼ section 24, 1 n., 14 w.....	Bog ore, selected, very free from iron ore...	75.40 ..	Geological Survey.
17	Worthen's diggings, section 30. 1 n, 13 w	Bog ore, black....	55.36 ..	Geological Survey.
18	W. ½ of n. e. ¼ of section 9, 1 n., 14 w. Holly Spring...	Black hard ore, croppings..	70.55 .	Geological Survey.
19	Sutton's and neighborhood. Section 1, 1 n., 15 w., and section 35, 2 n., 15 w	Average of samples from croppings, not assorted	43.64 ..	Geological Survey.
20	Same as 19	Assorted ore	68.05 ..	Geological Survey.
21	Old workings, n. e. ¼ of section 13, 1 n, 14 w	Average black ore	49.60 ..	Geological Survey.
23	Shaft of Chicago Company near same locality as No. 16	Average ore, unassorted....	45 23 ..	Geological Sur-

where the pig produced from them can be treated with that of better quality, they may sometimes be made more widely applicable.

An iron ore should carry, on an average, at least 30 per cent. of metallic iron, and this is far too low a proportion unless the mineral be a carbonate, or unless it contain a large percentage of limestone, so as to make its treatment easy. No profitable industry could be built upon ores of this grade, except under very unusual conditions, and very much better averages must be obtained in order to establish the business of iron smelting in Arkansas. From 35 to 45 per cent. of iron in the raw ores may be regarded as worthy of attention and further study. The higher the percentage, the less is the chance of refractory ingredients being present in unfavorable quantity, though comparatively small amounts of sulphur, phosphorus, titanium, etc., are objectionable. The best ores should ordinarily yield above 45 per cent. of iron.

Much depends, however, upon the mineral composition of the ore. Magnetite, if free from gangue, should contain from 65 to 70 per cent., and more of iron; hematite, when pure, is 70 per cent. iron, but the deposits of this ore are rarely as rich as this; the hydrous oxides goethite, turgite, and limonite, respectively contain nearly 62 per cent., 66.3 per cent. and 59 per cent. of iron. Usually these all contain more or less silica, alumina, sulphur, phosphorus, etc., and commonly the ores are mixtures of one or more of these three minerals with the contaminating ingredients named, besides other substances. An analysis should always show the percentages of metallic iron, silica, phosphorus, sulphur, lime and alumina, and a metallurgist would need to know also the relative amounts of protoxide and sesquioxide of iron.

The exact proportions of silica, sulphur and phosphorus may vary considerably without rendering the ores unfit for use, but the relations between them are of considerable importance as affecting the cost of treatment and the quality of the resulting pig metal. This is less so, however, than in the case of steel. The proportion of magnesia may also b or-

urnaces, and the intermediate works, but would de-
it all of these be near the factories. On the other
markets for the disposal of the manufactured articles
be very remote, for otherwise freights will reduce the
eyond the possibility of competition with producers
orably situated. If, then, the question of adaptability
res to iron making be favorably settled in given cases,
n more important to know what to do with the smelted
The future must determine the character and extent
markets within reach. Until the population has become
enough and sufficiently diversified in its industries, there
no large demand for staples in the iron trade, which will
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ction with the manufacture of tools and implements used in
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One very important question—the value and adaptability
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passed without special consideration. Assuming that the requisite amount of limestone is available for fluxing, let us briefly review some of the principal requirements of an ore suitable for the production of foundry pig and rolling mill pig.

THE LIMITATIONS OF ORES FOR FOUNDRY AND MILL IRON.

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CHAPTER XXIV.

The Iron Ores.

It will not be possible to present such a full statement concerning the ores of iron as is requisite for determining their commercial values in the different localities. At the outset, even the preparation of a general review of the distribution and modes of occurrence was not contemplated. For that reason very little chemical work has been done upon this portion of the collections, and in the field the examinations were necessarily made subservient to other investigations. But it has been deemed best to give such facts as have been gathered, hoping that they may to some extent simplify and diminish the labors of future workers in the same field.

Ores which to the novice may seem excellent, even if they contain very large percentages of iron, are often practically worthless as commercial products. The presence in excess of sulphur, phosphorus or other deleterious ingredients may disqualify otherwise valuable deposits to such a degree as to render them unfit for economic metallurgical treatment, at least by methods that can be regarded as thoroughly proven. The present chief obstacle to the utilization of grades of ore suitable for the production of pig iron for use in foundries and rolling mills, is the distance from available markets. Castings and bar iron are not yet extensively employed in manufactures in the State, and pig iron will not bear the cost of transportation to a distance. Mills and foundries cannot be maintained without the coincident development of local industries to absorb their products; and these industries again must have a certain market for their wares. To manufacture iron pipe or malleable iron castings, plows, stoves, nails, horse-shoes or any other much used commodity, would not only open the way for iron furnaces, and the intermediate works, but would demand that all of these be near the factories. On the other hand, the markets for the disposal of the manufactured articles must not be very remote, for otherwise freights will reduce the profits beyond the possibility of competition with producers more favorably situated. If, then, the question of adaptability of the ores to iron making be favorably settled in given cases, it is even more important to know what to do with the smelted metal.. The future must determine the character and extent of the markets within reach. Until the population has become dense enough and sufficiently diversified in its industries, there can be no large demand for staples in the iron trade, which will not be more economically supplied from without. If it happen that peculiar conditions of mining and transportation hereafter coexist in a manner favorable to cheap reduction of the ores, a vigorous supplying of the home markets with articles abundantly employed, or the tempting here of manufacturers of patented articles, will secure the best results. Good judgment will dictate the avoidance of investments in manufactures other than those which foster and stimulate the most natural demands of the citizens of Arkansas and of the adjoining states. There can be no doubt that the best prospects for remuneration in the iron industry of Arkansas, if such be feasible, are in connection with the manufacture of tools and implements used in mining and in agriculture. Other supplies can no doubt be profitably produced at a later date.

One very important question—the value and adaptability of the coals of the State to the metallurgy of iron—must be passed without special consideration. Assuming that the requisite amount of limestone is available for fluxing, let us briefly review some of the principal requirements of an ore suitable for the production of foundry pig and rolling mill pig.

THE LIMITATIONS OF ORES FOR FOUNDRY AND MILL IRON.

Ores can be used for the production of ordinary cas wrought iron that are not suited for making into s these can be mixed economically with better g where the pig produced from them can be treated with that of better quality, they may sometimes be made more widely applicable.

An iron ore should carry, on an average, at least 30 per cent. of metallic iron, and this is far too low a proportion unless the mineral be a carbonate, or unless it contain a large percentage of limestone, so as to make its treatment easy. No profitable industry could be built upon ores of this grade, except under very unusual conditions, and very much better averages must be obtained in order to establish the business of iron smelting in Arkansas. From 35 to 45 per cent. of iron in the raw ores may be regarded as worthy of attention and further study. The higher the percentage, the less is the chance of refractory ingredients being present in unfavorable quantity, though comparatively small amounts of sulphur, phosphorus, titanium, etc., are objectionable. The best ores should ordinarily yield above 45 per cent. of iron.

Much depends, however, upon the mineral composition of the ore. Magnetite, if free from gangue, should contain from 65 to 70 per cent., and more of iron; hematite, when pure, is 70 per cent. iron, but the deposits of this ore are rarely as rich as this; the hydrous oxides goethite, turgite, and limonite, respectively contain nearly 62 per cent., 66.3 per cent. and 59 per cent. of iron. Usually these all contain more or less silica, alumina, sulphur, phosphorus, etc., and commonly the ores are mixtures of one or more of these three minerals with the contaminating ingredients named, besides other substances. An analysis should always show the percentages of metallic iron, silica, phosphorus, sulphur, lime and alumina, and a metallurgist would need to know also the relative amounts of protoxide and sesquioxide of iron.

The exact proportions of silica, sulphur and phosphorus may vary considerably without rendering the ores unfit for use, but the relations between them are of considerable importance as affecting the cost of treatment and the quality of the resulting pig metal. This is less so, however, than in the case of steel. The proportion of magnesia may also become important; in the grades of ores now under consideration, the earthy constituents are of the greatest moment, as they effect the cost of treatment more than the other ingredients, the the latter being more readily removed in the after manipulation. Excess of sulphur may be removed by roasting, or by the use of lime or other substance in the fluxes. High phosphorus ores are improved in the process of puddling, and lime in the charge is a good corrective for an excess of silica. But the undue use of lime produces cinder which is difficult to fuse, thus increasing the cost of reduction and often seriously deranging the working of the furnaces. Aluminous iron ores, understandingly applied, can be utilized to overcome this annoyance, and it will be seen that the obstacles in the way of employing ordinary ores, where reasonable advantages exist and low costs prevail, are not insurmountable, although they demand the attention of persons skilled in the metallurgy of iron.

In prospecting for iron ores, it is not enough to procure even average samples of the croppings, but the deposits should be examined as far as possible beneath the surface, in order to determine the variations which may be anticipated in the future workings. It is a common mistake to suppose that the surface exposures are always less favorable than the deeper portions of ore masses. Many disastrous failures have resulted from too much reliance upon this idea.

THE GEOGRAPHIC DISTRIBUTION OF THE ORES.

Pulaski County.—No magnetites are known to occur in Pulaski county. A piece of lodestone was shown the writer in 1887, which was said to have been picked up at the "Fletcher diggings," but nothing like it could be found there. It resembled very closely the magnetic ore from Magnet Cove.

Hematite ores of uncertain value, although not yet opened to any extent, are exposed in situations very favorable for working, in several places near Little Rock. Some of these occur as shaly beds, portions of which may be found suitable for treatment alone or for enriching the leaner and more siliceous hydrated ores. If limestone occurs in the vicinity, only the simple question of fuel supply requires a favorable answer in order to solve the chief metallurgical problems. Earthy hematites, probably highly siliceous and often aluminous, abound in the district south of Little Rock, more especially at the southern end and upon the western flank of Fourche Mountain. It is highly probable that certain portions of this last named field will yield a much better quality than the average of the outcrops. A thorough examination of the area should be made at an early date.

The hydrous oxides, conveniently classed as limonites, although they do not all correspond exactly to this mineral in the proportions of their combined water, are abundant in the manganese district and in the belts south of that tract. There is little doubt that many of these contain iron enough to justify development whenever the economic conditions shall become favorable. Much study must be given to them, however, before the chemical relations and proportions of accessory ingredients, the requirements and possibilities of their treatment and the facts concerning their continuity and abundance in depth can be made known. The presence of manganese in excess, although it may make the ores valuable for other purposes, such as are mentioned in chapter xxiii, will not at present be advantageous in the manufacture of ordinary pig iron.* Bog ores abound in patches in the manganese district, but they will usually require concentration.

Saline County.—Magnetites should be diligently sought in the area of the meridional trends, particularly in ranges 16, 17 and 18, south of the base line. There is reason to believe that the magnetic iron ore of Magnet Cove, really known only as a local surface deposit, occurs in its original position in the oldest axes, or in one of them.

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*In the transitional state of existing practices, it may well happen that manganese will hereafter be regarded as an important ingredient in cases where it is now a detriment. But this remark can be extended to apply to the whole range of accessory ingredients, about which information is only beginning to be acquired by investigators.

Hematites may be sought near the base line in this county, especially west (and east) of the meridional axes, upon the latitudinal trends, where erosion has well exposed the lower black shales. Alum and Middle forks of the Saline river near their crossings of the base line, or northward, are probably the best places for prospecting.

Limonites, including all the hydrous oxides, are most abundant in the manganese and the manganiferous iron ore belts, but may be of value south of the base line and north of Benton. Near Blocher, and in the country adjoining, there are quantities of iron sinter, which has been produced by numerous springs. The source of this material has not been ascertained, but general indications favor the discovery of better ores beneath, or in exposures of the lower rocks in that region. The occurrence of gold in small amount, but more than elsewhere, in these deposits, may arise from a direct connection with the crystalline rocks in which the magnetite occurs. Bog ores are abundant in the manganese district, but they will require concentration.

Garland County.—Magnetites are not known in Garland county, but the remarks under Saline county apply here with even greater force. Reference is also made to the deflection of the compass needle, as given on page 56 of this report.

Hematites were noticed, or at least their waste, in several places in the northern part of the county where erosion has exposed the lower rocks.

Limonites have not been abundantly recognized in this county, except in the form of ferruginous sinters, which are probably too siliceous for profitable employment in iron metallurgy. Red and yellow sands appear upon Blakeley Mountain in apparently the same relations as those which are associated with the lower ironstones of Scott county.

Hot Spring County.—There is every prospect that careful search will reveal important deposits of magnetic iron ore in Magnet cove, but the actual position, thickness and importance of the bed or beds are as yet unknown. Hematite is not a common ore in the northern portion of the county, the only part examined by the writer.

Limonite and allied hydrates occur in connection with the manganiferous deposits of the Trap Mountains. Their relations are more indiscriminate, and less specialized than the outcrops in the Pulaski-Saline areas, but they appear to be near them in their geologic horizons. Investigation is needed to determine whether the original masses are accessible and of economic importance. In the surface deposits silica is liable to be the chief source of annoyance.

Polk County. —There is much hydrated iron oxide in the southern part of Polk county, in connection with the manganese belts, and in the southwestern part of the county it occurs in large, but apparently siliceous deposits. In some of the higher beds in the mountains south of Dallas, carbonate ores occur also, but no investigations of them have been made.

Scott County.—No magnetite was observed in Scott county, and only local occurences of hematite as a mixture with carbonated ore, in special situations of no economic importance were noted. Impure limonites occur in various places, sometimes as concretionary net-works in siliceous rocks, occasionally as sinter about springs, and in small local patches as bog ore. Much of the ironstone occurring as nodules and concretionary slabs may be of this character, but a large portion is apparently spathose ore, or iron carbonate, more or less impure. Some impure limonite from Tanner Hill gap in the Fourche Mountains yields 14.72 per cent. of sesquioxide, equivalent to only 10.3 per cent. of metallic iron.

At Cox's Alum Spring, section 5, 1 N., 28 W., the iron sinter formed about an old spring yields 64.92 per cent. of sesquioxide, or 45.4 per cent. of metallic iron. This is probably an aluminous ore, and not one of the most siliceous. Below Brawley, on Jones's creek, in the western part of Scott county, there is a heavy sintery deposit, from which specimens were taken. The following is an analysis of this ore,

Iron sesquioxide	44.25
Silica	37.65

Sulphur	Trace.
Phosphorus	Trace.
Water, organic matter and alumina	Undetermined.

This shows only 29.6 per cent. of metallic iron. It might be utilized by concentration and calcining. The limonite ores, and apparently the carbonate, are probably abundant enough in Scott county, if they can be economically mined and smelted.

Logan County.—Some of the nodules at Golden City are pyritous, but others are "clay ironstones." In the Aleck Thornton lode the cementing material of the conglomerate is a mixture of the spathose character with hematite. It is doubtful whether this can be separated from the mass of the conglomerate to good advantage.

Franklin County.—Large quantities of an ironstone resembling the "black band" low grade ores of Ohio, are found in the carboniferous sandstones, especially at and near Ozark. No data concerning the cost of mining or of the real quality of the ore have been procured, as the commercial utilization of the material has not been attempted. The masses occur as curved plates, nodules and interlacing bands, which weather out readily, but it is, as yet, uncertain whether the quality and quantity of the ore will warrant the removal of the enormous amount of sandstone with which it is associated. Nearness to fuel, and other considerations may make this feasible, if the ores be of a good grade.

CHAPTER XXV.

Notes upon Miscellaneous Products.

The following are a few additional notes incidentally made upon miscellaneous products in the region traversed. It should not be inferred, however, that the localities mentioned are the only ones yielding such products, or that by the absence of the names of other minerals from this list their non-existence is implied:

Graphite.—Graphite is abundant and pure in many localities in the Trap Mountains in Hot Spring county. It occurs also in the form of graphitic shale in Garland and Montgomery counties. Some of this material is in thick deposits of excellent quality, while some of it occurs in streaks or pockets only, and much is mixed with earthy matter. The impure varieties are available for paint, and are referred to below.

Silica Powder.—The pealite of the Sand Carbonate mine, in Saline county, and elsewhere among the ancient hot spring deposits, frequently occurs as a fine powder. This might be utilized profitably as polishing material, with or without further treatment.

Pyrites.—The constantly increasing use of pyrites in the manufacture of sulphuric acid is liable to make available in the future the large deposits which occur in Garland and Polk counties and elsewhere in the region. At present there is no market near enough to warrant extensive development. Wikel's mine, near Hot Springs, is most accessible; but the Towry lode, near Hatton gap, may be economically worked also. whenever railway transportation can be had.

MINERAL PAINTS.

Barytes.—There are some seams or pockets of a very good quality of barytes in many places in Montgomery county between the Broken Rock and Blue Mountain axes, and, generally speaking, along the whole length of that belt. Whether the material is abundant enough to establish an industry is rather doubtful, as some hand assorting will be required to separate the valuable portion from the shale. But, as it adds a possible source of revenue in the development of the silver deposits, the occurrence may become advantageous. The average value for the crude ore is $5 per ton, but owing to the purity of the material in the localities mentioned a better price should be obtained, provided the yellowish or brownish color due to the presence of small percentages of iron be not a disadvantage. The best prepared barytes brings from $15 to $30 per ton at St. Louis. Some of it is white and more valuable. This is an industry worthy of consideration.

Black Earths.—Much of the "black mud," "blue mud," etc., is a naturally ground shale, and this would probably meet a ready sale under favorable conditions of transportation and local markets. Several thousand tons of refuse slate are now annually ground for the purpose of obtaining "fillers" or "body" for carriage paints and roofing paints. Impure graphite is also used in this way to a limited extent. Tests of these substances, which abound in the region, especially in Montgomery county, should certainly be made. They may prove unsuitable, but if such application be feasible, profits may be reasonably anticipated from the ease and low cost of mining these deposits.

Graphitic Shales.—Certain of the "blue muds" and many shaly beds, within the region in Garland, Montgomery, Hot Spring and Polk counties, in which thermal springs have formerly been active, carry much graphite. This material, pure and impure, is now largely employed in paint manufacture. With favorable commercial conditions, not now existing, there is hope of the utilization of much of this material in this manner.

Ochre and Ochreous Earths.—Red ochre (hematite) and "reddle," or a kind of red chalk, are abundant in many localities. Use might be made of these probably in paint manufacture, though it may not be advantageous to ship them to outside markets at present. The yellow and brown ochreous earths (limonite) may in some cases be useful for similar purposes. The quantity of each ore, particularly in Pulaski county south and west of Little Rock, is enormous and easily mined. Some reddish ochre in the mines near Bear City, containing much manganese, may also be serviceable.

CHAPTER XXVI.

TABLE IV.

List of the Minerals of Western Central Arkansas.

This list includes more than 140 distinct species or varieties of minerals occurring within the region to which this report relates. The information here given is as complete as it can be from the field and office studies thus far undertaken. No opportunity has been presented for making thorough quantitative chemical analyses of doubtful species, nor for determining the exact relations of such minerals as appear to be new to science. All that can now be said upon this latter point is that the determinations here given and the undetermined minerals collected, taken together, do not probably constitute more than half of the whole number of species existing within the area traversed. There are very few minerals heretofore reported, however, that are not in the accompanying list; and besides these, many are here given which have not been reported before, while the distribution of those previously accredited to the region is very much extended.

In order to make the table useful to the largest possible number, a full set of synonyms and popular names is employed, in addition to the technical terms which are necessary to insure accuracy of record. The list is arranged alphabetically in the column of names. Each mineral has a concise statement of its chemical composition, modes of occurrence and the localities in which it has been observed, but where more than one name is used for the same species, the data concerning it are given but once. In every case of this kind, reference is made to the place in the table where the description will be found, and great care has been taken to make this method of consultation as easy and satisfactory to the readers as possible.

Signs and abbreviations are used as follows:

(Syn.) signifies that the mineral name preceding is synonymous with the title name in the first column. Thus, under *Amphibole* in the third column, *Hornblende* (Syn.) implies that *Hornblende* is another name for *Amphibole.*

(Var.) signifies that the mineral name before it is a variety of the *title* name. Thus, under *Brookite* is given *Arkansite* (Var.), meaning that *Arkansite* is a variety of *Brookite.*

(Alt.) Shows that the name which it immediately follows is that of a mineral produced by the alteration of the *title mineral;* as, under *Perofskite,* the signification of *Hydrotitanite* (Alt.) is that the latter is an alteration product from the former.

Names printed in italics in the first column, as *Actinolite,* are recognized scientific or technical names of different minerals.

Names given in ordinary Roman type, as Alum, are popular titles, which are not always definite.

A ? placed after the name of a mineral indicates a doubt of the correctness of a determination or whether a given deposit is of the species named; in other columns this mark expresses doubt of the statement preceding.

TABLE IV.

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Actinolite	Magnesium-calcium-iron silicate (Amphibole)	Occasional in granitic rocks	Magnet Cove.
Aegirite	Aluminium-calcium-iron-soda silicate; near pyroxene, with alkalies	In granitic rocks, with labradorite; also enclosed in microcline	Magnet Cove; near Hot Springs; near McAllister's mill, Saline county.
Agalmatolite	Hydrous alkaline silicate. (Pinite group.) (See Pyrophillite)	In pockets in shale, and as "selvage" in quartz seams	Saline county; Garland county, commonly; generally distributed in other counties.
Agaric Mineral	Calcium carbonate. See Calcite (Syn.)	Fine powdery incrustations on rocks or in crevices	Coating of silvery shale, Montgomery county; in Peacock lode, Logan county.
Alaskaite ??	A "gray copper" ore allied to Freibergite but containing bismuth	Among rich silver minerals of Silver City or Silver Hill district, if at all	Very doubtful.
Albite	Sodium-aluminium silicate. (Feldspar)	Sparingly in granitic rocks	Near Magnet Cove, Hot Spring county; Potash Sulphur Springs, Garland county. ?
Allophane	Hydrous aluminium, silicate	Incrustations in crevices, etc	Hot Spring county, near Magnet Cove; Garland county.
Almandite	Iron-aluminium silicate. (See Garnet)	Crystals abundant in wash, also in granitic rocks	Magnet Cove.
Alum	See Halotrichite.		
Aluminite	Aluminium sulphate	This, or a closely allied earthy mineral in tertiary clays	Pulaski, Saline, Hot Spring, Pike, Sevier and Polk counties, and northward.
Amethyst	Silica (Quartz)	Rare, and not highly colored	Montgomery county; Yell county, occasionally.
Amphibole	Variable silicate	See Actinolite (Var.), Hornblende (Syn.)	
Anatase	See Octahedrite (Syn.)		
Andradite	Calcium-iron silicate. (Garnet.) (Aplome.) See Melanite (Var.)	As in Almandite	Some of Magnet Cove garnet belongs here.
Anglesite	Lead sulphate	Rarely, in oxidized portions of lead bearing veins, near surface	Kellogg mine, Pulaski county; Silver Cit region, Montgomery county; Antimony region (west belt) and Silver Hill district, Sevier Co.
Ankerite	Calcium-magnesium-iron carbonate	In seams, crevices, etc., and in larger masses, in calcareous rocks. Shades into dolomite and calcite	Magnet Cove; near Golden City, Logan Co.
Antimony glance	See Stibnite (Syn.)		
Antimony ochre	See Cervantite, Stibiconite (Syn.)		

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Brown Spar	See Ankerite, Dolomite	Transition from dolomite to ankerite, which see.	
Brucite	Hydrous magnesium oxide	Occasional in masses of serpentine	Saline county.
Calcite	Calcium carbonate. See also Calc-sinter, Chalk, Dog-tooth spar. Agaric Mineral	In seams and pockets in black shale; as gangue of silver ores, also in mounds and local beds. Crystals commonly large, rhombohedrons most abundant, but the other forms occasional	Pulaski and Saline counties, not abundant. Plentiful in Magnet Cove in large masses; in veins and patches, Silver City district; Sevier county, antimony and silver mines; Polk and Scott counties less common; plentiful in seams in black shale, at Golden City, Logan county.
Calc-Sinter	Calcium carbonate. See Calcite. See Travertine	In stalactitic and similar formations, locally about old springs, etc	Magnet Cove; Garland and Montgomery counties, occasional.
Calc-Spar	See Calcite, (Syn.) etc.		
Calc Tufa	See Calc-Sinter (Syn.) See Travertine (Syn.)		
Cancrinite ?	Basic anhydrous silicate and carbonate	Doubtful. In granitic or felsitic rocks. Most of the material which might be taken for cancrinite is altered eleolite	In regions where eleolite rocks have been exposed to weathering and carbonated waters.
Capillary Pyrites	See Millerite (Syn.)		
Cerargyrite ?	Silver chloride. (Horn silver.)	Doubtful, if at all, in small patches in quartz	Silver City mines, if at all.
Cerussite	Lead carbonate	Small quantity, from alteration of galena. Associated with silver ores	Silver City district, uncommon; probably small amount at Kellogg mine, Pulaski county, occasionally.
Cervantite	Yellow antimony oxide	From alteration of stibnite	Antimony mines, Sevier county.
Chalcanthite	Copper sulphate	In crevices and as incrustations, very sparingly	Montgomery and Sevier counties, and Polk county, near deposits of copper pyrites subject to oxidation. Rare.
Chalcopyrite	Copper sulphide	Crystals, chiefly in silver districts, but occasional elsewhere	Kellogg mine; Silver City region and its continuation through Polk, Howard and Sevier counties; section 28, 4 s., 31 w., Polk Co.; Silver Hill mines, Sevier county.

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Chalk	Calcium carbonate	In tertiary, running into calcareous clays and marls	Pike county.
Chalybite	See Siderite (Syn.)		
Chert	Silica (Quartz)	In beds and masses. Much of the so-called "novaculite" is impure flint or jasper, of this kind	Garland and Hot Spring counties, adjacent to Magnet Cove; Caddo gap, Montgomery county; Trap Mountains, west to Indian Territory, through Polk county.
Chrysolite	Magnesium-iron silicate. Olivine (Syn) Peridot (Syn.)	In crystals and disseminated grains in igneous and metamorphic rocks, some peridotites	Fourche Mountain and northwards; Pulaski county and Saline county; Magnet Cove.
Cinnamon Stone	Aluminium-calciumsilicate. (Aluminium-lime garnet.) Grossularite (Syn.)	In "float" and in metamorphic rocks	Magnet Cove. Part of the Garnet seems to be of this species, but shading into Almandite.
Clay-Ironstone	Impure iron carbonate. See Siderite (Syn.) See Hematite (Syn)	In concretions in grits, etc., but sparingly	Occasional westward.
Cobalt ore	See Earthy Cobalt.		
Coccolite	Var. of lime-magnesia Pyroxene (Malacolite)	In granitic rocks	Magnet Cove, (green coccolite.)
Copper	Native copper	Very small quantities, occasionally in black shales. Reported.	
Copperas	Iron sulphate. (Melanterite), strictly, but blue vitriol (Chalcanthite) is included popularly		Melanterite appears to be more abundant than chalcanthite.
Copper Carbonate	See Azurite (Syn.)		
Dog-Tooth Spar	See Calcite. (Var.)	Less common than rhombohedrons	Magnet Cove; particularly in silver districts though not abundant.
Dolomite	Calcium-magnesium carbonate	In beds interstratified with grits above the tripartite shales. Perhaps some also below this horizon more siliceous. Also associated with sepentinous rocks	McAllister's mill, Saline county; Magnet Cove; Garland and Montgomery counties, northward; Yell, Howard, Sevier and Polk counties

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Brown Spar	See Ankerite, Dolomite	Transition from dolomite to ankerite, which see.	
Brucite	Hydrous magnesium oxide	Occasional in masses of serpentine	Saline county.
Calcite	Calcium carbonate. See also Calc-sinter, Chalk, Dog-tooth spar. Agarie Mineral	In seams and pockets in black shale; as gangue of silver ores, also in mounds and local beds. Crystals commonly large, rhombohedrons most abundant, but the other forms occasional	Pulaski and Saline counties, not abundant. Plentiful in Magnet Cove in large masses; in veins and patches, Silver City district; Sevier county, antimony and silver mines; Polk and Scott counties less common; plentiful in seams in black shale, at Golden City, Logan county.
Calc-Sinter	Calcium carbonate. See Calcite. See Travertine	In stalactitic and similar formations, locally about old springs, etc	Magnet Cove; Garland and Montgomery counties, occasional.
Calc-Spar	See Calcite, (Syn.) etc.		
Calc Tufa	See Calc-Sinter (Syn) See Travertine (Syn.)		
Cancrinite ?	Basic anhydrous silicate and carbonate	Doubtful. In granitic or felsitic rocks. Most of the material which might be taken for cancrinite is altered eleolite	In regions where eleolite rocks have been exposed to weathering and carbonated waters.
Capillary Pyrites	See Millerite (Syn.)		
Cerargyrite ?	Silver chloride. (Horn silver.)	Doubtful, if at all, in small patches in quartz	Silver City mines, if at all.
Cerussite	Lead carbonate	Small quantity, from alteration of galena. Associated with silver ores	Silver City district, uncommon; probably small amount at Kellogg mine, Pulaski county, occasionally.
Cervantite	Yellow antimony oxide	From alteration of stibnite	Antimony mines, Sevier county.
Chalcanthite	Copper sulphate	In crevices and as incrustations, very sparingly	Montgomery and Sevier counties, and Polk county, near deposits of copper pyrites subject to oxidation. Rare.
Chalcopyrite	Copper sulphide	Crystals, chiefly in silver districts, but occasional elsewhere	Kellogg mine; Silver City region and its continuation through Polk, Howard and Sevier counties; section 28, 4 s., 31 w., Polk Co.; Silver Hill mines, Sevier county.

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	Composition.	Occurrence.	Localities.
…omite			
…AME.			
Earthy Cobalt	Ferriferous variety. Brown Spar, in part Cobaltiferous variety See Asbolite (Syn.)	…ng into calcareous clays and	Pike county.
Eleolite	Alkaline aluminium silicate … phelite	Much of the so-called … ure flint or jasper, of	Garland and Hot Spring counties, adjacent to Magnet Cove; Caddo gap, Montgomery county; Trap Mountains, west to Indian Territory, through Polk county.
Embolite ?	Silver chloride …	…s in igneous … idotites	Fourche Mountain and northwards; Pulaski county and Saline county; Magnet Cove.
Fahlunite			Magnet Cove. Part of the Garnet seems to be of this species, but shading into Almandite.
Feather Ore	Variety …		…ccasional westward.
Feldspar			…Cove, (green coccolite.)
Girasol	Silic…		
Gold	Native gold		
Goethite	Hydrous iron sesquioxid…		
Graphite	Carbon	In beds … shale, grap… mud," etc., alw… members of the tripa…	
			…ars to be more abundant than
Gray Antimony	See Stibnite (Syn.)		…early in silver districts
Gray Copper	See Freibergite, Tennantite, Tetrahedrite	One of these minerals in very thin coating on blocks of quartz, with chalcopyrite, etc.	Blocks at Shippe,
Grossularite	See Cinnamon Stone, Garnet	Grossular rock and other non-crystalline or crypto-crystalline forms	Magnet Cove and adjoinin…
Gypsum	Calcium sulphate	Not abundant in district examined, as far as observed	Near chalybeate springs where pyrite… stone are associated, as in parts of Sa… county.
Halotrichite	Iron alum (Syn.)	Incrustations in black shale	Sloan's well, Black Spring, Montgomery county; Cox's Alum Springs near Boles, Scott county.

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Dolomite	Ferriferous variety. Brown Spar, in part	In pockets and crevices, and in weathered portions of some dolomites	Trap Mountains, Hot Spring county; Polk, Scott and Logan counties, and elsewhere.
	Cobaltiferous variety	Not very common, but probably the source of cobalt in certain rocks	Silver World mine, Polk county. Worthington's mines, (Copper and Queen lodes) Polk county. Localities given under Asbolite also yield this mineral.
Earthy Cobalt	See Asbolite (Syn.)		
Eleolite	Alkaline aluminium silicate. Variety of Nephelite	In coarse crystals in granitic rocks; also in massive rocks	Distribution general and abundant in regions of metamorphic rocks. Pulaski, Saline, Garland, Hot Spring, Montgomery, Pike and Polk counties.
Embolite ?	Silver chloride and bromide	Barely possible that this occurs in connection with silver "bonanzas"	Said to be a constituent of Silver City veins, especially Minnesota mine. Not seen.
Fahlunite	Hydrous silicate of Hydro-mica group. (Hydrous lime mica)	From alteration of Iolite. Usually in granitic or hornblende rocks	Magnet Cove, etc.
Feather Ore	See Jamesonite (Syn.)		
Feldspar	See Albite, Microcline, Oligoclase, Orthoclase, Labradorite	Felsite rocks, of the species orthoclase or oligoclase, are rare.	
Fiorite	Siliceous sinter (Opal). In form of Pealite, etc	Products of hot springs	Sand Carbonate mine, Saline county. See Pealite.
Freibergite	Argentiferous antimony-copper sulphide. Var. of Tetrahedrite (Gray Copper)	With galena, zinc blende and chalcopyrite in silver regions, in gangue and quartz	Kellogg mine; Silver City district; Silver district, Sevier county.
Galena, or *Galenite*	Lead sulphide	In beds instratified with shales (interbedded veins); in veins occupying fault fissures; associated with blende, copper pyrites, etc. Occasionally in sparsely disseminated crystals in quartz	Kellogg mine. Very little at McRae mine, Pulaski county; in quartz veins, Silver City district; same belt s.w through Howard and Sevier counties. Silver and antimony belts. Sparingly in Polk county, south of Dallas,

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Garnet	Include here Almandite, Andradite, Grossularite. See Schorlomite	All occur in "float," also in garnet rock (grossular) and in granitic and feldspathic rocks	Magnet Cove.
Geyserite	Silica (Opal). See Pealite, Fiorite, Girasol, Siliceous sinter. (Opal)	In heavy deposits covering large areas, but of varying character. See under special names	Porcelain variety (Girasol?) like Yellowstone Park deposits north of Magnet Cove, at "Spanish diggings."
Girasol	Silica (Opal)	About ancient hot spring bowls, with tendency to cuboidal jointing.	
Gold	Native gold	Very rare, traces only in most cases—these in pyrite, galena, etc., seldom in quartz.	
Goethite	Hydrous iron sesquioxide	Rarely in scaly tubular crystals; occasionally in radiating prisms (needle ironstone); more often reniform or massive. In connection with limonite and manganese ores	Manganese and iron ore belts, Pulaski and Saline counties; less common in other districts.
Graphite	Carbon	In beds and heavy deposits, also as graphite shale, graphitic shale, "black mud," "blue mud," etc., always associated with other members of the tripartite shale series	Trap Mountains, Hot Spring county, excellent and abundant, but in shaly and impure forms all over the region where black shales are exposed, in Garland, Montgomery, and adjoining counties. Not so apparent in outside counties.
Gray Antimony	See Stibnite (Syn.)		
Gray Copper	See Freibergite, Tennantite, Tetrahedrite	One of these minerals in very thin coating on blocks of quartz, with chalcopyrite, etc	Blocks at Shippey mine, in ravine below shaft.
Grossularite	See Cinnamon Stone, Garnet	Grossular rock and other non-crystalline or crypto-crystalline forms	Magnet Cove and adjoining areas.
Gypsum	Calcium sulphate	Not abundant in district examined, as far as observed	Near chalybeate springs where pyrite and limestone are associated, as in parts of Saline county.
Halotrichite	Iron alum (Syn.)	Incrustations in black shale	Sloan's well, Black Spring, Montgomery county; Cox's Alum Springs near Boles, Scott county.

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Halloysite	Hydrous alumina silicate. Allied to kaolinite	Possibly deposits of fine clays may be of this character. Investigation needed	Manganese district near Martindale, Pulaski county; Montezuma mine, Garland county; the latter is highly ferruginous. The mineral species of both is not determined, but included here to call attention to them.
Heavy Spar	See Barite.		
Hematite	Anhydrous iron sesquioxide	In beds (specular) of hematite shale; possibly some of the clay ironstone of western counties is also this mineral. Also associated with porphyries, and as tertiary iron sands or clays	Specular, in many places; horizon of hematite shale, between black shales; Pulaski, Saline, Garland, Hot Spring and Montgomery counties; red sands and clay. Fourche Mountain, Pulaski county; s. w. of Caddo gap, Montgomery county; Pike county; Scott and Franklin counties. Other varieties only occasional.
Hornblende	Aluminous magnesia-lime Amphibole	In syenites	Diamond Jo quarry and other places near and in Magnet Cove.
Horn Silver ?	See Cerargyrite (Syn.)		
Hornstone	Silica (quartz). See Chert	Much of the bedded "novaculite" is of this character	Garland, Hot Spring, Montgomery and Polk counties.
"Horse Tooth" quartz	See Siliceous sinter.		
Hydrotitanite	Altered Perofskite	In crystals, locally, form perofskite, but gray color	Magnet Cove.
Hypersthene	Magnesia-iron silicate	Some of the labradorite rock, bearing brookite crystals, has also this mineral	Magnet Cove.
Idocrase	Aluminium calcium-iron-magnesia silicate. Vesuvianite (Syn.)	As idocrase rock, sometimes with imbedded crystals	Magnet Cove.
Iolite	Alumina silicate, with other bases	In metamorphic rocks, rarely in unaltered condition. See Fahlunite, Pinite, for altered forms	Magnet Cove, and northward in Garland and Saline counties.
Iron, Magnetic	See Magnetite. (Syn.)		
Iron Pyrites	See Pyrite (Syn.) Marcasite, Pyrrhotite.		

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Iron Sinter	Iron sulphate, etc., and iron oxide (variable)	Springs, etc., near pyrite deposits	At various places over the district, probably a number of varieties. See under Pitticite.
Ironstone	See Siderite, Hematite, Limonite.		
Jamesonite	Lead-antimony sulphide	With stibnite, galena, etc., in veins. Fine capillary crystals in quartz, occasional	Sevier county antimony mines.
Jasper	Silica (quartz)	Of various colors, among the ancient hot spring deposits; so-called "novaculites"	Garland and Hot Spring counties; Montgomery county; Caddo gap, Polk county; Eagle Hill.
Jefferisite	Aluminium-magnesium-iron silicate. Micaceous, swells enormously when highly heated	Associated with aegerite-rock, and among other metamorphic rocks, as serpentine	North of Magnet Cove; Garland county; Hot Spring county; south of Hot Springs; McAllister's mill, Saline county; Montgomery county.
Kaolin, or *Kaolinite*	Hydrous aluminium silicate. See also Halloysite	Beds and local deposits, where igneous rocks have been much weathered. Frequently impure from siliceous or ferruginous admixtures	Fish creek, Fourche Mountain, Pulaski county. Other localities reported. Special deposits also in and near Magnet Cove.
Labradorite	Aluminium-calcium sodium silicate. Lime-soda feldspar	As base of intrusive rocks; in basaltic and other basic rocks	Fourche Mountain, Pulaski county; McAllister's, Saline county; Magnet Cove.
Limonite	Hydrous iron sesquioxide. See also Goethite. Often manganiferous	Several varieties from ochreous to compact, including bog ore, brown clay ironstone, etc.; in beds parallel to manganese ore beds; in bogs, in pockets and crevices, also in concretionary forms	Manganese and iron districts, Pulaski and Saline counties; Garland county, Montezuma tunnel and elsewhere; Magnet Cove; Trap Mountains; Mammoth lode, Ozark mine; Pike, Howard, Sevier, Polk, Scott, Logan and Franklin counties; common.

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Manganese ores	See Asbolite, Braunite, Bog manganese, Manganiferous iron ore, Pyrolusite, Psilomelane, Wad	Probably other varieties. All occur in beds, bogs, pockets or crevices	Manganese districts, Pulaski and Saline counties; Polk county and elsewhere.
Manganiferous Iron Ore	Var. of Limonite, containing considerable manganese	Associated with limonite and pyrolusite	Pulaski and Saline counties, manganese and iron districts.
Magnetic Iron Ore	See Magnetite (Syn.)		
Magnetic Pyrites	See Pyrrhotite.		
Magnetite	Iron proto- and sesqui-oxides. Ferroso-ferric oxide. Magnetic iron ore (Syn.)	In crystalline metamorphic rocks; in a local deposit at surface and in soil in fragments; magnetic	Magnet Cove, abundant.
Malacolite	Non-aluminous, lime-magnesia Pyroxene	Represented by variety coccolite, which see.	
Marcasite	Orthorhombic iron disulphide. (White Iron Pyrites)	In quartz, associated with pyrite, millerite and pyrrhotite. Carries some nickel	Rabbit Foot mine, Saline county.
Marmatite	Ferriferous zinc sulphide. See Sphalerite	In beds and veins	Kellogg mine; section 26, 1 n., 16 w., Saline county ("float").
Melanite	Lime-iron Garnet. Black variety of Andradite; or Aplome, which see	Loose crystals and in rock	Magnet Cove.
Melanterite	Iron vitriol	In incrustations, etc., rarely pure	Rabbit Foot mine, Saline county.
Mellite	Alumina mellitate. (Honey stone)	As incrustations on sandstones of coal measures	Scott and Franklin counties.
Microcline	Alkaline alumina silicate. Triclinic potash-feldspar	Greenish, in granitic rocks, with aegerite; orthoclase or albite, sometimes associated with it	Garland county, Potash Sulphur Springs; Magnet Cove.
Millerite	Nickel sulphide. Capillary Pyrites. (Syn.)	In hair-like crystals and in leathery or matted, flakes in cavities of honey-comb quartz; also in crevices in the quartz	Rabbit Foot mine, Saline county.
Nephelite	See Eleolite. (Var.)		
Novaculite	Silica (quartz). Not a mineralogical term but now recognized as a trade name for quartz rock suitable for whetstones. Quartz altered by silicified water	In special deposits or patches in altered quartz chiefly near ancient hot spring orifices, though not in all of these	Hot Spring and Garland counties

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Ochre, brown	Limonite, (Syn.)	Very little of this is pure, but it is usually contaminated with clay	See localities for limonite.
Ochre, red	Hematite (Syn.) See also Turgite	Usually impure from admixture with silica or clay	Fourche Mountain and suburbs of Little Rock.
Octahedrite	Titanic oxide. Anatase (Syn.) Close to Rutile. See also Brookite	Occurs sparingly with Brookite, Rutile and Arkansite, also as imbedded crystals in feldspathic or garnet base	Magnet Cove.
Oligoclase	Triclinic soda-lime feldspar	With orthoclase in metamorphic (granitic) rocks· Not very abundant, apparently. In syenite, more or less	Magnet Cove.
Olivine	See Chrysolite (Syn.)		
Opal	Silica. See Girasol, Fiorite, Siliceous sinter, Geyserite, Pealite	In certain ancient hot spring deposits, in the varieties named in the adjoining column to the left.	Magnet Cove, and northward in Garland county. Not as common in other regions of spring deposits. Usually in local relics, such as so called "Spanish diggings."
Orthoclase	Potash feldspar	In granites and allied rocks, usually light colored	Fourche Mountain, Pulaski county; s. w. of Benton, Saline county; Magnet Cove.
Ozarkite	Hydrous aluminium silicate, with calcium and sodium. Massive variety of Thomsonite. (Zeolite)	In masses like beds or intrusious of uncertain relations	Magnet Cove and northeastward.
Pealite	Silica. Variety of Opal, or Fiorite	In crumbling masses, usually with hard nuclei. Constituent of old hot spring throats	Sand Carbonate mine, Saline county. Old hot spring bowls, near Magnet Cove, locally known as "Spanish diggings;" old hot spring deposits in Garland county, at Hot Springs and northwestward.
Peridot	See Chrysolite (Syn.)		
Perofskite	Titanic and calcium oxides. See Hydrotitanite (Alt.)	In cubes, octahedrons, etc., and fine twin crystals	Magnet Cove, s. w. of magnetic iron ore.
Petroleum	Hydro-carbon of marsh-gas series	Inspissated, in dolomite, not known as workable deposit	S. w. Scott county; n. base of Fourche Mountains.

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Pinite	Hydrous alkaline silicate. Speckstein (Syn.) See Agalmatolite. A group well represented, but needing more study	In granitic rocks, pseudomorphous after Iolite? Also other species probably pseudomorphous after nephelite and other minerals.	Magnet Cove. Other members of the pinite group occur here and elsewhere. Pinite schist occurs at junction of quartz with black shale.
Plumbago	See Graphite (Syn.)		
Prase	See Quartz	Old deposits of altered quartz	North of Magnet Cove in Garland county; Caddo gap.
Pseudobrookite	Titanic and iron oxide	An iron bearing mineral, near brookite, is probably this	Magnet Cove.
Psilomelane	Maganous oxide with other bases	Reniform and stalactitic, with other manganese ores	Pulaski county manganese district.
Pyrite	Iron disulphide	Very common, often in beds or veins. Rarely auriferous, with traces of gold	Wikel's pyrite deposit, East Mountain; Mt. Ida road, near Hot Springs; Towry's claims, s. w. Polk county; nodules in workings at Golden City, Logan county.
Pyrolusite	Manganese dioxide	In beds or veins in contact with black shale and quartz-rock; in pockets, as concretionary deposits and in bogs	Pulaski-Saline manganese districts; northern Garland county; Una and Buena Vista lodes, Hot Spring county; Ward's mine, Polk county.
Pyrophyllite	Hydrous aluminium silicate. Part of Agalmatolite belongs here	Occurs in serpentine and steatite	Saline county soapstone district, eastern end.
Pyroxene	Variable bisilicate. See Coccolite (Var.) and Malacolite (Var.)	Only the non-aluminous green coccolite has been distinctly recognized, but other varieties may occur	Magnet Cove.
Pyrrhotite	Variable iron sulphide	In quartz, with nickel ore. May occur otherwise, but not detected	Rabbit Foot mine, Saline county.

TABLE IV.—*Continued.*

Name.	Composition.	Occurrence.	Localities.
Quartz	Silica. See Amethyst (Var.) Aventurine quartz (Var.) Basanite (Var.) Chert (Var.) Hornstone (Var.) Jasper (Var.) Siliceous sinter, smoky quartz (Var.) Novaculite	The most abundant mineral. As beds intercalated with black shales, in veins, in pockets, masses, crystals, sands, etc In connection with the ancient hot spring deposits but not in the bowls, mass of prase, (green quartz) False topaz, (yellow quartz) etc., are abundant	Beds of white quartz, in manganese districts, Pulaski and Saline counties; buff beds in Saline, Garland, Montgomery and Polk counties; white beds, Trap Mountains, Hot Spring, Montgomery, Pike, Polk counties Distributed over the above counties In veins or metalliferous beds Kellogg mine; Saline county, north of McAllister's; Rabbit Foot mine. Hot Spring and Garland counties in many places; Montgomery county; Silver City district; Howard and Sevier counties, less northward. Rock crystal at Crystal Hill, Montgomery county, and region about; Linyear lode. Garland county; crystals with liquid cavities at Crystal Hill. Rose quartz occasional.
Rock Crystal	See Quartz.		
Rose Quartz	See Quartz.		
Rutile	Titanic oxide	In loose crystals and in metamorphic rocks, imbedded	Magnet Cove. Abundant in float. Used as coloring for artificial teeth.
Schorlomite	Calcium-iron silicate, and titanic Near Staurolite	Crystals, scattered	Magnet Cove. Dr. Koenig of Philadelphia finds the schorlomite reported from this locality to be titaniferous garnet.
Serpentine	Hydrous magnesium silicate. See Bowenite (Var.)	Usually massive or in grains	In beds or masses of wide extent. 10 miles n. of Benton. In imbedded patches in quartz, north of Blocher, Saline county.

TABLE IV.—*Continued.*

NAME.	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Siderite	Iron carbonate. Chalybite (Syn.) Spathic iron (Syn.) Spherosiderite (Var.)	In crystals, occasionally; in earthy and tufaceous deposits, more or less impure, about chalybeate springs; in nodules and concretions in coal measures	Crystalline, Kellogg mine, and near Magnet Cove, with calcite; earthy, about a few chalybeate springs west of Magnet Cove, nodulary and concretionary, in higher sandstones of coal measures, Scott and Franklin Cos.
Silex	Silica. Name sometimes used as synonymous with quartz.		
Siliceous sinter	Silica. Opal or quartz, which see	Pealite is opal, and occurs in places where ancient hot springs made surface deposits	North of Magnet Cove, at 'Spanish diggings;' near Hot Springs, Glenpatrick lodes; near Golden Crown lode, n. w Garland county; about some of the mines in Silver City district.
		Quartz sinter is not very common, but has been formed as coarsely cellular masses in some instances	Silver World mine, Polk county; on road Mt. Ida to Black Spring. Montgomery county, and elsewhere.
Silver Ore	The silver is contained in such minerals as Freibergite, Tennantite, Tetrahedrite; more commonly in Galenite, etc	I have been unable to make careful mineral analyses, but my observations make it appear that antimony, rather than arsenic, is the prevalent accompaniment of the silver. T. B. C	See chapter XVII, and the minerals named in 2nd column.
Smithsonite	Zinc carbonate	Crystallized, with blende and galena	Kellogg mine.
Smoky Quartz	Silica. Variety of Quartz	In vein-like portions of beds; apparently more common in the regions where millstone grit is exposed	Magnet Cove; Garland county, and few other districts Somewhat rare in showy crystals.
Soapstone	Hydrous magnesium silicate. Steatite (Syn.) Talc (Syn.)	In massive beds, underlying slabby sand-rock	Wallis' quarry, 12 miles n. of Benton (section 15, 1 n. 15 w) Saline county, also eastward.
Spathic Iron	See Siderite (Syn.) Clay ironstone (Syn.)		
Specular Iron	See Hematite (Syn)		

TABLE IV.—*Continued.*

NAME.	COMPOSITION	OCCURRENCE.	LOCALITIES.
Sphalerite	Zinc sulphide. See Marmatite (Var.) Blende, or Zinc blende (Syn.)	In beds and veins with galenite, chalcopyrite and silver ores	Silver City mines, Montgomery county; Silver Hill mines, Sevier county; s. e. Polk county. Marmatite (dark colored) is more common.
Spherosiderite	Concretionary siderite	Concretionary siderite.	
Stannite	Tin sulphide. Tin Pyrites, (Syn.)	Suspected. in small quantity. because pyritous rock shows traces of tin	Silver World mine, Polk county.
Steatite	See Soapstone (Syn.) Talc (Syn.)		
Stibianite and *Stibiconite*	Antimony oxides Antimony ochre	Alteration products from stibnite	Stibiconite occasional in surface ores of Antimony mines, Sevier county.
Stibnite	Antimony sesqui-sulphide. Antimonite (Syn)	Abundant and pure, with other antimony ores, in veins	Antimony district, Sevier county.
Talc	Hydrous magnesium silicate. Steatite, (Syn.) See Soapstone (Syn.)	Talcose shales and talc schists in beds and pockets, with black shale	Saline county; near Hot Springs and in Garland county; Magnet Cove; in silver region of Montgomery county.
Tennantite	Arsenical copper sulphide. See Gray Copper, silver, ore, etc	As with other silver bearing minerals	Kellogg mine.
Tetrahedrite	Copper-antimony sulphide, normal argentiferous variety Freibergite	As with other silver ores. Variable in silver contents; sometimes very rich	See under Freibergite.
Thomsonite	See Ozarkite, (Var.)		
Thuringite	Hydrous iron silicate	In pockets and hot spring deposits	Hot Springs and northward in Garland county; Mozambique tunnel ?
Tin Pyrites	See Stannite (Syn.)		
Topaz, False	See Quartz.		
Travertine, or Tufa, calcareous	Calcium carbonate Calc-tufa (Syn.)	Deposited by springs and streams, locally; impure and not abundant	In northern districts where dolomites outcrop, Yell and Garland counties, also n. Polk Co.
Turgite	Hydrous iron sesquioxide. Resembles Limonite and Hematite	Botryoidal and reniform, also earthy (so-called Red Ochre)	Same as under Limonite and Hematite; especially in mid-regions.
Variscite	Hydrous aluminium phosphate. Near Peganite and Turquois in composition	In veins of quartz, and in concretionary patches in dolomites	Silver City district, Montgomery county.

TABLE IV.—*Continued.*

NAME	COMPOSITION.	OCCURRENCE.	LOCALITIES.
Vesuvianite	See Idocrase (Syn.)		
Wad	Hydrous manganese dioxide? Results of decomposition of other ores. See Bog Manganese. Not a distinct species	In pockets in quartzite, etc	Bluish, radiated, or tufted masses. Lost Louisiana mine, Montgomery county, and at other mines in the region.
Wavellite	Hydrous aluminium phosphate	Common in radiated, spherical and hemispherical crystalline aggregations, and in similar forms thickly spread over rock surfaces	Magnet Cove, Hot Springs, Silver City and neighboring districts
Whetstone	See Novaculite.		
Wulfenite ??	Lead molybdate	Occurrence very doubtful	Said to occur at Ozark mine as "black mud." Nothing resembling wulfenite was seen in this mud.
Zinkenite	Antimony-lead sulphide. Less lead and more antimony than Jamesonite	With stibnite and galenite and other ores, in quartz veins	Antimony mines, Sevier county.

CHAPTER XXVII.

On the Location of Mining Claims.

So many questions have been put to the Geological Survey regarding the methods of locating mineral claims and the formalities necessary to hold them, that it has been thought best to give a brief review of the subject in this volume of the report.

The lands in the State may be divided into four general classes, according to the nature of the titles under which they are held. These titles need be considered here only so far as they affect the discoverers and investors in mining property. These classes are:

1. United States government lands.
2. Lands of the State of Arkansas.
3. Railroad grants.
4. Deeded lands, or lands owned by private individuals, or corporations under titles acquired by entry, purchase or otherwise.

When a discovery of valuable mineral has been made, or when one proposes to purchase land containing such deposits, the first thing to be ascertained is the status of the land itself. It may belong to the United States government, in which case it will be necessary to determine the nature of the title under which it can be acquired. If it be found that the tract in question lies upon State land, or on railroad or private lands, the next step will be radically different.

LOCATIONS UPON UNITED STATES LANDS.

The policy of the United States, as expressed in its mining laws, is to encourage the development of the mineral bodies upon its domain. Therefore, however imperfectly this end may be accomplished, it is usually to the interest of the locator to make known his discovery very soon after it is made. This may not be the case with discoveries upon other land, if the finder be unable to perfect his purchase at once.

The Status of the District.—Considered from the standpoint of one who has found a deposit which he wishes to locate, there are two classes of mineral claims upon government land. Having ascertained that this is certainly upon unsold and unclaimed United States property, the next step is to decide to which of these classes it belongs.

1. If it lie within a district which has never been reserved as "mineral area" by the United States Land Office, it may be entered and secured as ordinary government land by one or other of the processes of pre-emption, homesteading, etc. But, unless one is able to purchase outright, there is danger in such proceeding, for a homestead or agricultural entry will be canceled, if any mineral claim upon it be substantiated prior to the issue of the patent. A patent once secured, however, carries with it the rights to the mineral.

2. It may lie within an established "mineral area," which means that the United States Land Office has withdrawn from sale as homestead and agricultural land all the real estate within prescribed limits, of which tract the claim in question forms a part. In such case, the method of procedure will be dictated by the character of the mineral discovered, as explained below.

The Character of the Mineral.—The mining laws of the United States make a distinction between coal and all other mineral deposits. Coal lands are sold by the acre, in legal subdivisions (forty acre tracts and upwards), at $10. per acre, when fifteen or more miles from any railroad, and at $20. per acre if within fifteen miles of a railroad. Individuals are limited to 160 acres and corporations to 320 acres, although more may, of course, be purchased from other locators. Everything besides coal, that can be located as mineral deposits, is classed together without regard to composition, but a separation is made, based upon the position of the deposits, as defined in the following paragraph.

The Position of the Deposit.—Two classes of deposits are recognized by the laws, and the method of location and manner of holding title are somewhat different in them. There are also two kinds of claims which may be called adjunct locations.

I. *A Lode Claim and Its Location.*—A lode claim is one based upon the discovery of a "vein or lode of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits." It is important to determine whether the vein or deposit be "in place" between other rocks. The courts have usually decided that there must be country rock upon both sides of the deposit of ore; otherwise it should be located as a placer claim.

The locator must be a citizen of the United States, or must have "declared intention" to so become. He need not be a citizen of Arkansas in order to locate claims within the State upon United States land. One or more persons may locate, and there is no limit to the number of lode claims that may be taken by an individual, or an association of individuals, corporate or otherwise.

The size of each claim is limited to 1500 feet in length and 600 feet in width. This can never be exceeded; if more is taken the excess will be excluded from the patent, and the portion allowed will be what the location certificate calls for; therefore it is important to define the boundaries carefully in the first place. The end lines of the claim must be parallel, the side lines need not be, nor need they be in one continuous line; but no portion of any side line can pass more than 300 feet from the vein, if properly placed. State laws may reduce the limits of size, but they cannot extend them. Arkansas has no law upon this subject, therefore the United States law is in force in the State without limitation, as far as the land of the national government is concerned.

It is a peculiarity of our mining law that in working a lode claim the owner cannot pass beyond the plane of his end lines continued downward perpendicularly, but he may pass out of his side lines beneath adjoining property wherever his vein or deposit may lead. He acquires no surface rights, except within the area of the boundary lines at the surface, but in the direction of the dip he may follow indefinitely, so long as he does not cross an end line or leave his mineral deposit. Any ore-body outcropping within his surface lines belongs to the locator, with only the restriction named above. There must, however, be an actual discovery for the original location, or the claim cannot be held against later discovery.

In locating a lode claim in Arkansas, the following procedure is best, care being taken to have witnesses to all important papers:

First—Upon the discovery of mineral make sure that it is in place; then uncover it enough to enable a witness to prove the discovery. The United States law requires that "the location must be distinctly marked on the ground so that its boundaries can be readily traced." The laws of some states further specify the manner of establishing boundaries by stakes and other means, but there is no Arkansas requirement of this kind. The United States law also provides that records of location "shall contain the name or names of the locators, the date of location, and such description of the claim by reference to some natural object or permanent monument, as will identify the claim." In the absence of special state legislation, all that is necessary in the notice of location to be posted upon the ground, is a brief statement to comply with this law.

Second—Place a notice on the claim at the discovery opening, simply claiming the lode by name, and stating the distance claimed in each direction, by compass, from the "discovery" also the width claimed on each side of the vein or lode. Permanent stakes should be set at each corner of the claim. Under the U. S. laws no more work is required until one year from the 1st day of January next following the date of location. Thus, if a lode claim be located January 2, 1889, or at any time in that year, no labor, beyond that required to prove discovery, need be done upon it until January 1, 1891; but if located December 31, 1888, the assessment work must be performed on or before January 1, 1890. The law requires that "not less than one hundred dollars worth of labor shall be performed, or improvements made, during each year," after the first "assessment" period. This may consist of almost any kind of expenditures for mining purposes, including roads, buildings, diggings, etc., and it need not be done upon the surface of the claim, provided that it is plainly intended for the use of the property in mining. The law particularly provides that work done in a tunnel, or cross-cut, intended to develop a claim or claims, may be regarded as "assessment work" upon the properties themselves.

The title thus acquired cannot be taken away except by failure to work "assessments." While these are kept up, the title is as good as a patent. If a co-owner fail to contribute his proportion of the expenditure required, the other partner or partners may comply with the law and give the delinquent "personal notice in writing, or notice by publication in the newspaper published nearest the claim, for at least once a week for ninety days," after which time, if he still be delinquent, his share of the claim is forfeited to those who have contributed.

Third—To complete the location, a certificate stating the facts should be prepared, and filed with the Recorder of the county or mining district in which the claim is situated. A survey is desirable, though not always required. If this be had, a copy of the field notes should be placed upon record. It is also a good plan to file after each "assessment," an affidavit that the labor has been performed according to law, although this is not absolutely necessary.

I. *A Placer Claim and its Location.*—According to law, a placer claim includes "all forms of deposit, excepting veins of quartz or other rock in place." For "placer" locations, the "legal subdivisions of forty acres may be subdivided into ten-acre tracts," if desired. Individuals are limited to 20 acres, and associations cannot locate in one claim more than 160 acres, for which at least eight persons must unite. Expenditures upon placer claims are not required, but the Land Office is very strict in demanding proof that the mineral has actually been found and worked upon them, before a patent is allowed. It is best to work assessments upon such claims. Instructions for location are the same as given under Lode Claims in the preceding sub-heading. Placer claims containing lodes, must except the latter, which can only be separately claimed.

A Mill Site may be located on non-mineral land "not contiguous to the vein or lode," but not above five acres in one location; and "the owner of a quartz mill or reduction works, not owning a mine in connection therewith, may also receive a patent for his mill site" upon the same terms. The price paid for the mill site will be the same per acre as for the lode. Work done upon a mill site may count for the lode located in connection with it.

A Tunnel Claim, or Tunnel Site, is a location made for the discovery of deposits by means of a tunnel. The law relating to this class of claims provides that "the owners of such tunnel shall have the right of possession of all veins or lodes within three thousand feet from the face of such tunnel, on the line thereof, not previously known to exist, discovered in such tunnel, to the same extent as if discovered from the surface," and during the prosecution of the work, others cannot acquire title to "blind lodes" in the line of it; "failure to prosecute the work on the tunnel for six months" forfeits the "right to all undiscovered lodes." The "line of the tunnel" is its own width only. No definite expenditure is required to maintain possession title of tunnel claims.

SECURING U. S. PATENTS TO MINERAL LANDS.

The process of obtaining a patent is not perfectly simple, and it is attended with considerable cost. Anyone desiring to get such a title must employ an official surveyor, and in case of adverse claims the questions at issue have to be decided by the State courts before the U. S. Land Office will issue the patent. The following outline is all that can be given here:

The claim is first surveyed by a U. S. Deputy Mineral Surveyor upon the order of the Surveyor General of the Division. Full proofs of citizenship, location, possession, and of the expenditure of not less than five hundred dollars upon each lode or placer claim, are presented under oath, with a copy of the field notes of the official survey and a plat of the claim. The Surveyor General makes two certified copies of these, the original being kept in his office. One copy of the plat and notes is posted on the claim, and another is conspicuously placed in the office of the Register of the District Land Office. Publication of application for sixty days is required, during which time adverse claimants must appear or forfeit all rights. A patent is issued if no adverse claims are advanced. Adverse claims must be settled by the courts. Only one claim can be included in each application, except that a lode and its mill site may be patented together, as may also a placer claim and the included lode. Certain fees must be paid upon application and entry. Lode claims must be purchased at five dollars per acre, placer claims at two dollars and fifty cents per acre. Mill sites are paid for as lode claims. A full lode claim embraces about twenty-three acres. A patent for mining claims has no reservations. No patent cân be obtained upon a tunnel site.

LOCATIONS UPON STATE LANDS, RAIDROAD GRANTS, AND DEEDED LANDS.

Land grants to states cannot convey mineral lands which have been thus classified by the land office, but as none of the U. S. government lands in Arkansas were so designated until recently, the title to the mineral in this State in lands owned by the State and by the railways, is vested in the present owners. Nearly all the property held by individuals has been purchased without reservation of the minerals. It is, therefore, only necessary to purchase property of these classes in order to obtain mineral rights, unless these are specially reserved. It is becoming customary in Arkansas to make such reservations in deeds, and sometimes the mineral rights may be, in other cases they must be, separately purchased.

The State law, passed in 1887, creating the Geological Survey, provides that State lands found by the State Geologist to contain valuable minerals shall be withdrawn from sale. At present there is no law under which such lands can be acquired.

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